Files are in Adobe Acrobat 3.0 format.

44th Annual Fuze Conference

11-12 April 2000

Table of Contents

Tuesday, April 11, 2000

Wednesday, April 12, 2000

Rockwell Collins' Artillery GPS Engine - Smart Navigation Solutions for Future Munitions Systems by Mr. Tom Mills* and Mr. Kurt Grigg, Rockwell Collins

Portable Inductive Artillery Fuze Setter (XM1155 PIAFS) by Mr. Thomas W. Walker,* and Mr. Andrew M. Leshchyshyn, TACOM-ARDEC

Developing an Automatic Inductive Fuze Setter for Crusader by Mr. Bob Keil,* Alliant Techsystems Inc. and Mr. Tom Kilian, United Defense

Improved Artillery Proximity Fuze by Mr. Robert Hertlein,* and Mr. David Lawson KDI Precision Products Inc.; Mr. Telly Manolatos, Electronics Development Corp.

Experimental Characterization of M745 Explosive Train by Mr. Dennis Ward, TACOM-ARDEC

GIF Performance and Implementation Issues in Air Defense Missions by Mr. Milton E. (Gene) Henderson, Jr.,* U.S. Army Aviation & Missile Command and Mr. Graham C. Killough, KBM Enterprises Inc.

Joint Advanced Missile Instrumentation (JAMI) Flight Termination Safe Arm (FTSA) by Mr. Robert McWhorter,* NAWC, and Mr. Dale Spencer, Kaman Aerospace Corp., Raymond Engineering Operations

Machine Vision for Industrial Automation by Mr. Mitch Stone, Day & Zimmermann, Inc.

Submunitions Dispensing Overview by Mr. John Whaley, PRIMEX Aerospace Co.

Pumice as a Sympathetic Detonation Barrier by Mr. John Kandell* and Mr. Ed Cykowski, NAWC China Lake

Update on the Modernization of the Holston Army Ammunition Plant by Mr. Andrew Wilson, British Aerospace-RONA, Holston AAP

Development of a Unique Hypervelocity Composite Sabot by Mr. Moreno White, SPARTA, Inc.

Processing of R3 Pressed Molding Powder by Mr. Kirk Newman* and Mr. Richard Hardy, NSWC

Injection Loading of Aluminized PBX by Mr. Kirk Newman* and Mr. Neal Cowan, NSWC

Twin Screw Extrusion of GEM S&T Gun Propellant by Mr. Mitch Gallant, NSWC, Indian Head Division

Rocket-Assisted Ammunition Technologies for 120mm Mortars by Mr. Serge Montacq, TDA Armaments

Army Materiel Command

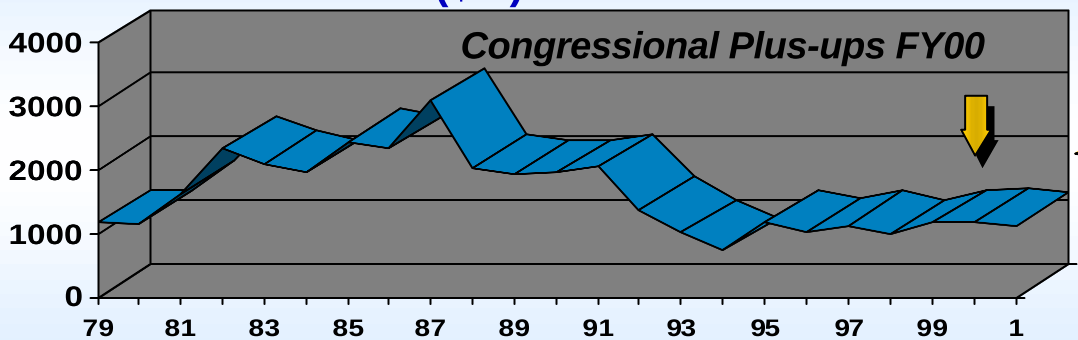
Presented by:
Harvey Burnsteel
Office of the DCS for Ammunition

Ammunition Update to NDIA Fuze Conference

11 April 2000

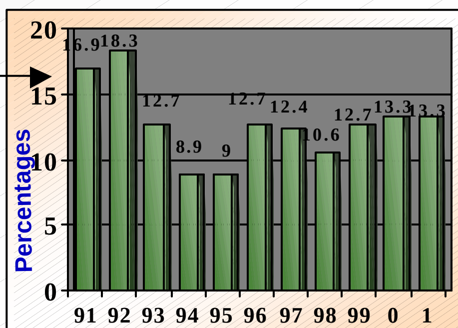
AMC – *Your READINESS Command . . . Serving Soldiers PROUDLY!*

PAA - Funding Profile



Today's Production Reflects Yesterday's Funding

Procurement as a Percentage of Army Budget - FY00/FY01



Army Budget
($ in Millions)

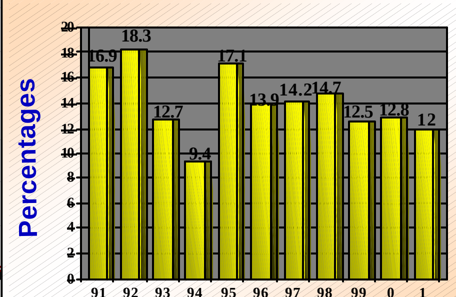
APPROPRIATION	FY00	FY01
FAMILY HOUSING	1,152	1,140
MIL PERSONNEL	27,748	28,380
RDTE	5,225	5,260
MCA	1,432	1,039
OMA	23,550	23,827
PROCUREMENT	**9,296**	**9,421**
ERA	376	390
BRAC	144	303
CHEM DEMIL	1,024	1,004
AWCF	62	
TOTAL*	70,010	70,765

*Totals may not add due to rounding

Procurement Appropriation
($ in Millions)

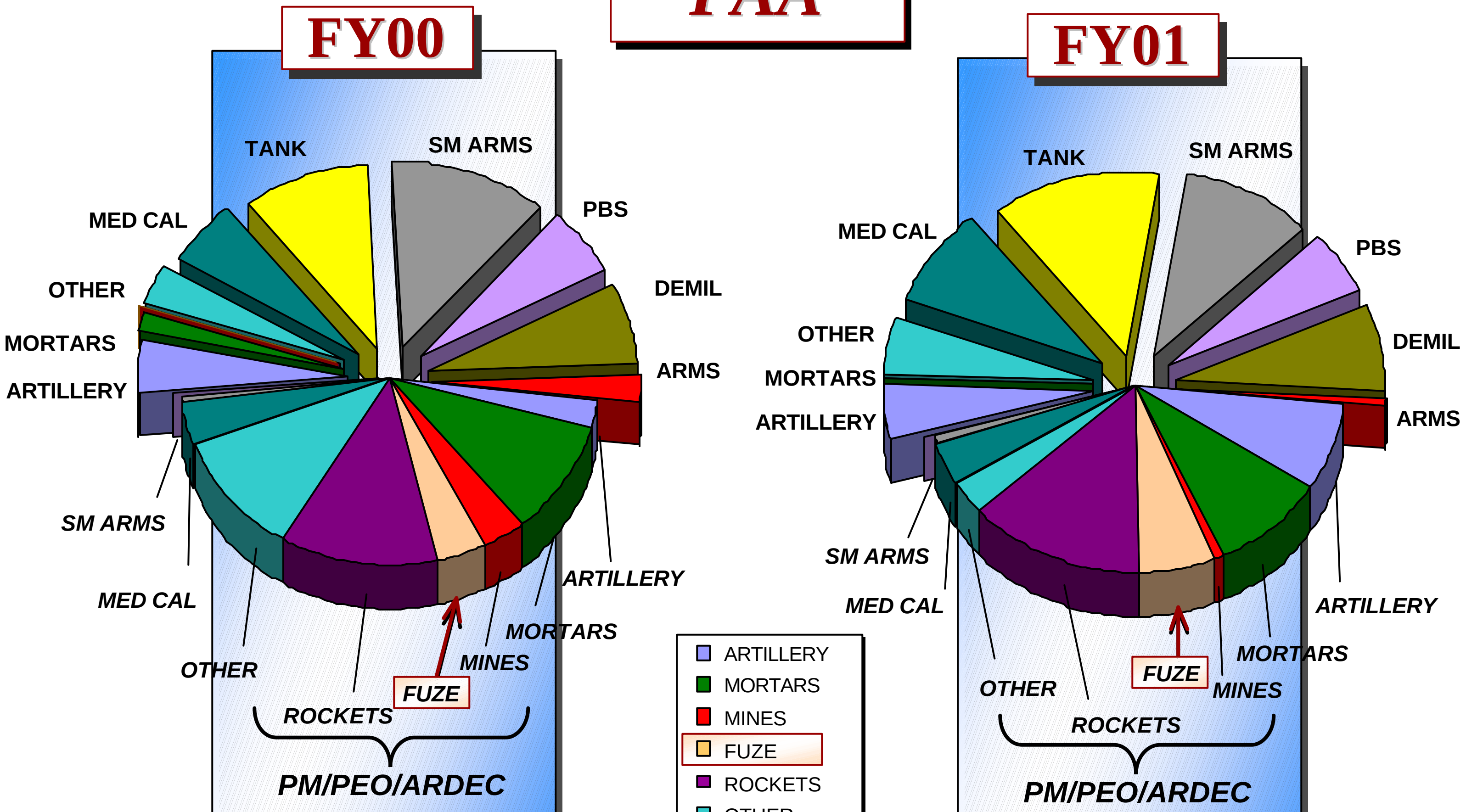
APPROPRIATION	FY00	FY01
AIRCRAFT	1,452	1,323
MISSILES	1,310	1,296
WTCV	1,571	1,875
AMMUNITION	**1,193**	**1,131**
OTHER PROCUREMENT	3,770	3,796
TOTAL	9,296	9,421

Ammunition as a Percentage of The Procurement Budget - FY00/FY01



Army Ammo Funded Requirements

PAA



FY00

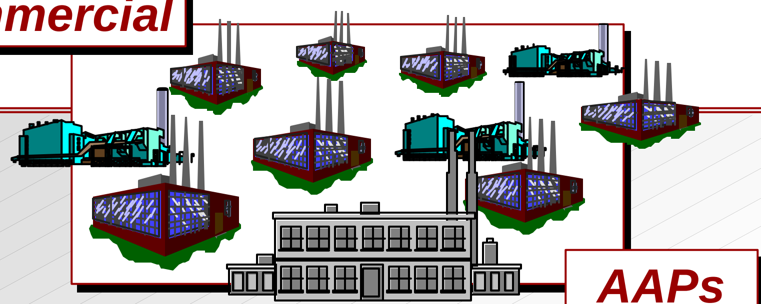
IOC	$630.6M
PM/ PEO/ARDEC	$559.8M

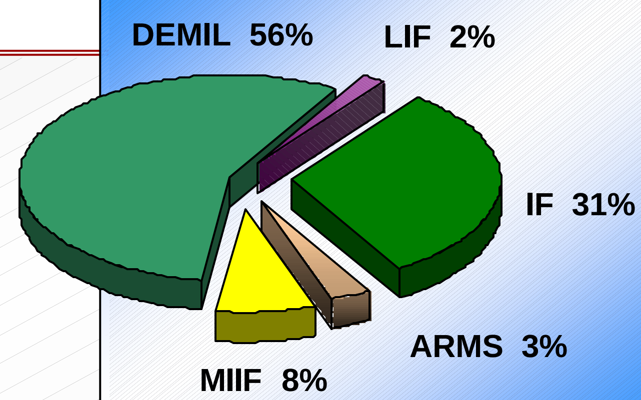
FY01

IOC	$625.8M
PM/ PEO/ARDEC	$503.3M

Ammunition Production Base Support

FY01 Budget





Activity 2 PAA Funding

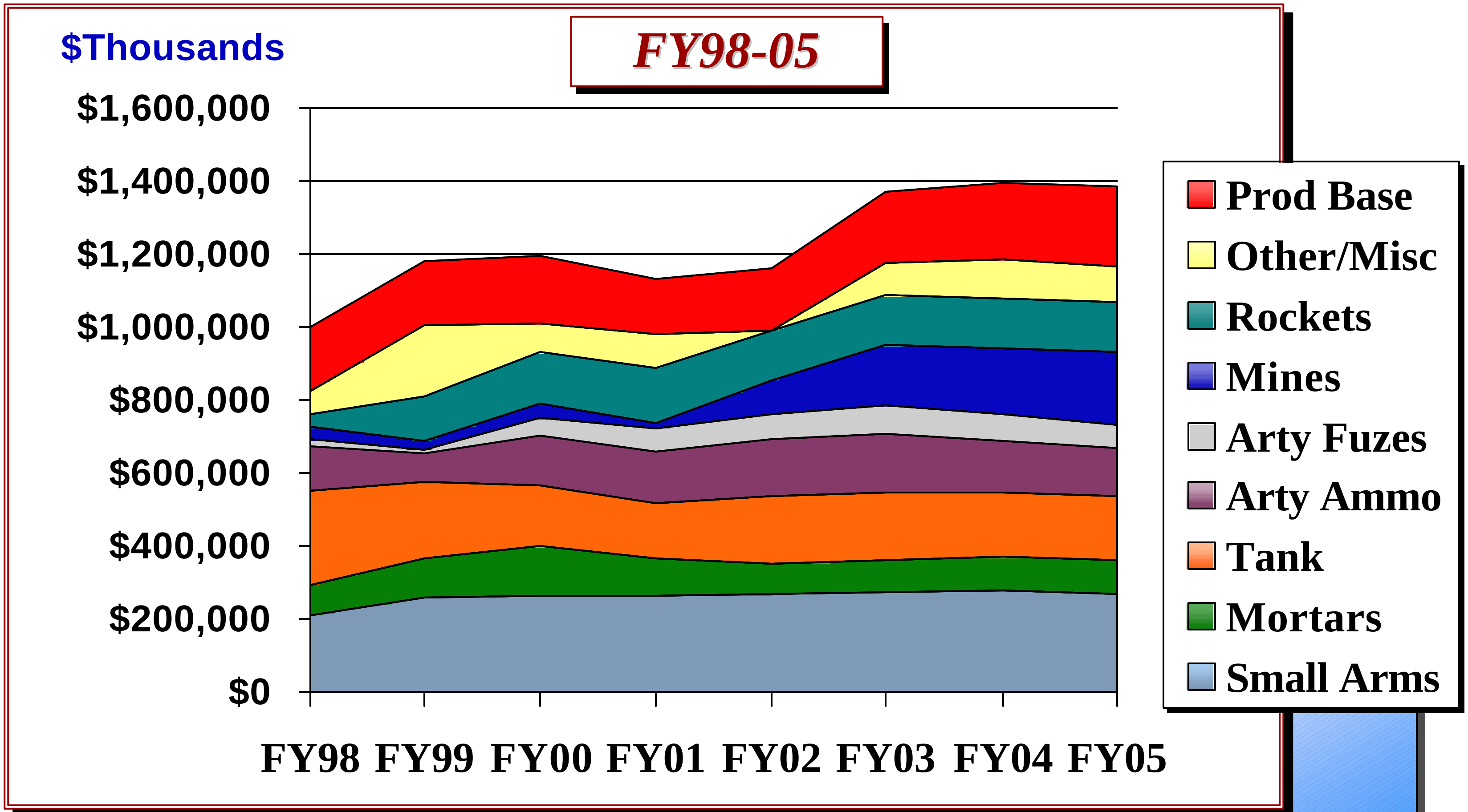
	$ Million FY99	FY00
Industrial Facilities (IF)	52.9	47.7
Layaway of Industrial Facilities (LIF)	3.5	3.2
Maintenance of Inactive Facilities (MIIF)	12.9	12.3
Conventional Ammo Demil	85.6	84.8
ARMS Initiative	26.4	4.7
Totals ($ in Mil)	**181.4**	**152.7**

Challenge

Privatization & Commercialization

Ammunition Procurement Projection

by Categories



Multi-Year Procurements

- *Ammo MYP*
  - 120mm Tank Training Ammo - M865 and M831A1
  - Medium Caliber
  - 155mm Metal Parts f/ M107
- *Multi-Year Programs underway:*
  - Fuze M762A1/M767A1
  - M782 Multi-Option Fuze for Artillery (MOFA)
  - Medium Caliber (40mm) Grenades
  - Aircraft Flares

Functional Area Assessment

A Process That Allows Senior Army Leaders to Identify and Resolve Issues Which Affect HQDA Short Range Plans and Programs By

- **Providing for Exchange of Information Between HQDA and FAA Participants**
- **Focusing on Maintaining Readiness, Force Capability, and Force Modernization in the POM Years**

Examines Where We Are, Where We're Going, & The Overall Health of Each Functional Area

Thereby Ensuring That as the Army Evolves Into the Restructured Force, Each Functional Area has a Coordinated, Cost-effective Transition Plan

Bottom Line Up Front

Assessment

Introduction

- Requirements
- Ammunition Technology - Underfunded, missing opportunities
- Missile Program
- Ammo Program
  - Training Program, solid 02-03, declines thru 07
  - War Reserve Modernization for heavy forces, good, support to vision, weak
  - Precision Fires, Insufficiently funded in the POM
  - Production Base, weak, some munitions cannot be replenished
- Stockpile Management

Conclusion

Munitions Funding Goals

- **Build a Balanced & Executable Munitions Program With Moderate Risk (Rely on Substitutes).**
- **Ensure Munitions Modernization Synchronized with System Modernization, i.e. 120MM Mortars - Ammo.**
- **Fully Support Training at Historic Expenditure Levels (includes Pipeline).**
- **Ammo: Procure Modern Items to at Least 50% Level; Maintain Older War Reserve Items to Support Min Risk Strategy; Buy at Min Production Rate.**
- **Missiles: Procure to DAB/ASARC Level at Most Affordable Rate.**
- **Fund Demil to Reduce Backlog to *100K S/T by 2010*; Prod Base to Moderate Risk w/ DPG; Stkpl Mgmt to Sustain Critical Workload Levels and Training.**
- **Support of Transition Force: Provide ammo to support fielding of two new brigades each year.**

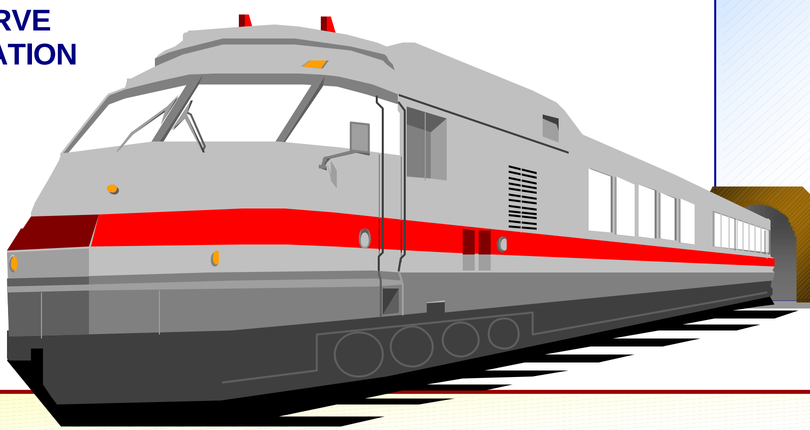
Requirements Drive the Train

Requirements Development

NATIONAL MILITARY STRATEGY - 2 MTWs
- DRIVES: Center for Army Analysis, (CAA)
- CAA PRODUCES QWRRM
- STRAC

Reqmts Categories

- WAR RESERVE
- MODERNIZATION
- TRAINING



What Gets Driven

✴PROCUREMENT OF MUNITIONS
- WHAT, & QTYS DRIVE: HOW MUCH PROD BASE & WHERE AT

✴DEMILITARIZATION

✴STOCKPILE MANAGEMENT (OMA)
- ISSUES/RECEIPTS & SDT
- INVENTORY
- SURVL, SAFETY & SECURITY
- MAINTENANCE
- REWAREHOUSING
- DEMILITARIZATION

RESULT: Balanced Funding Strategy Reflected In FAA & POM Build

Ammo Program Assessment

- *Training: Significant shortages FY04 and beyond. Some units not C1. Training Ammo Distribution also affecting readiness*
- *Available RDTE stretching key precision munitions programs -delaying munitions availability*
- *Modernization Program Adequate. Need more attention on INITIAL/INTERIM force modernization ammo.*
- *Precision munitions not being procured insufficient quantities to meet Army Vision*
- *Production Base Funding marginal, can not make up preferred munitions shortfalls during MTW, replenishment outside of DPG 3-year interval for several critical/preferred munitions*

Army will meet FY05 Precision Munitions Requirements in FY15

Current ammo program funding not adequate to maintain readiness or modernize stockpile

How Long Can We Rely on Aging Stockpile?

- *Increasing signs of age in current stockpile - major suspensions in 60MM, Mechanical Time Fuzes, older 120MM tank ammunition*
- *Ongoing controversy on non-self destruct 'cluster munitions' may affect inventory of 4 million+ DPICM munitions and MLRS -potential $22B bill to replace/remanufacture with Self-destruct fuzing*
- *Over $100M in deferred maintenance on stockpile munitions - backlog growing*

Army is facing need to recapitalize conventional munitions stockpile within next 10 years

Fuze Base Concerns

Since 1995, you have expressed your concerns:

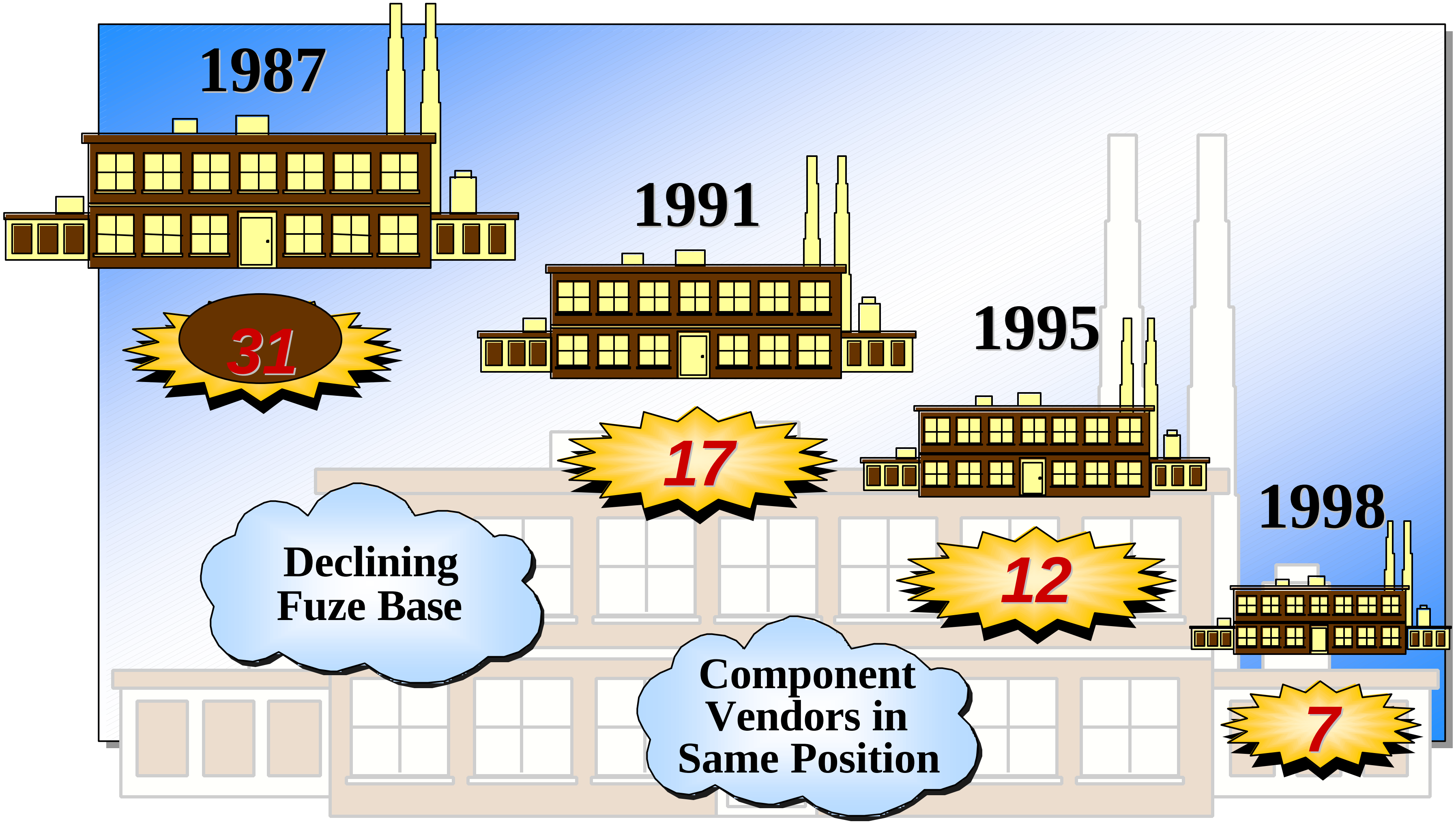
- **Declining Business Base**
- **Reduced Availability of Explosive Components**
- **Electronic Component Obsolescence**
- **Limited Fuze Development Opportunities**

AFMO Fuze Base Study 1997

DCS Ammo Approach:

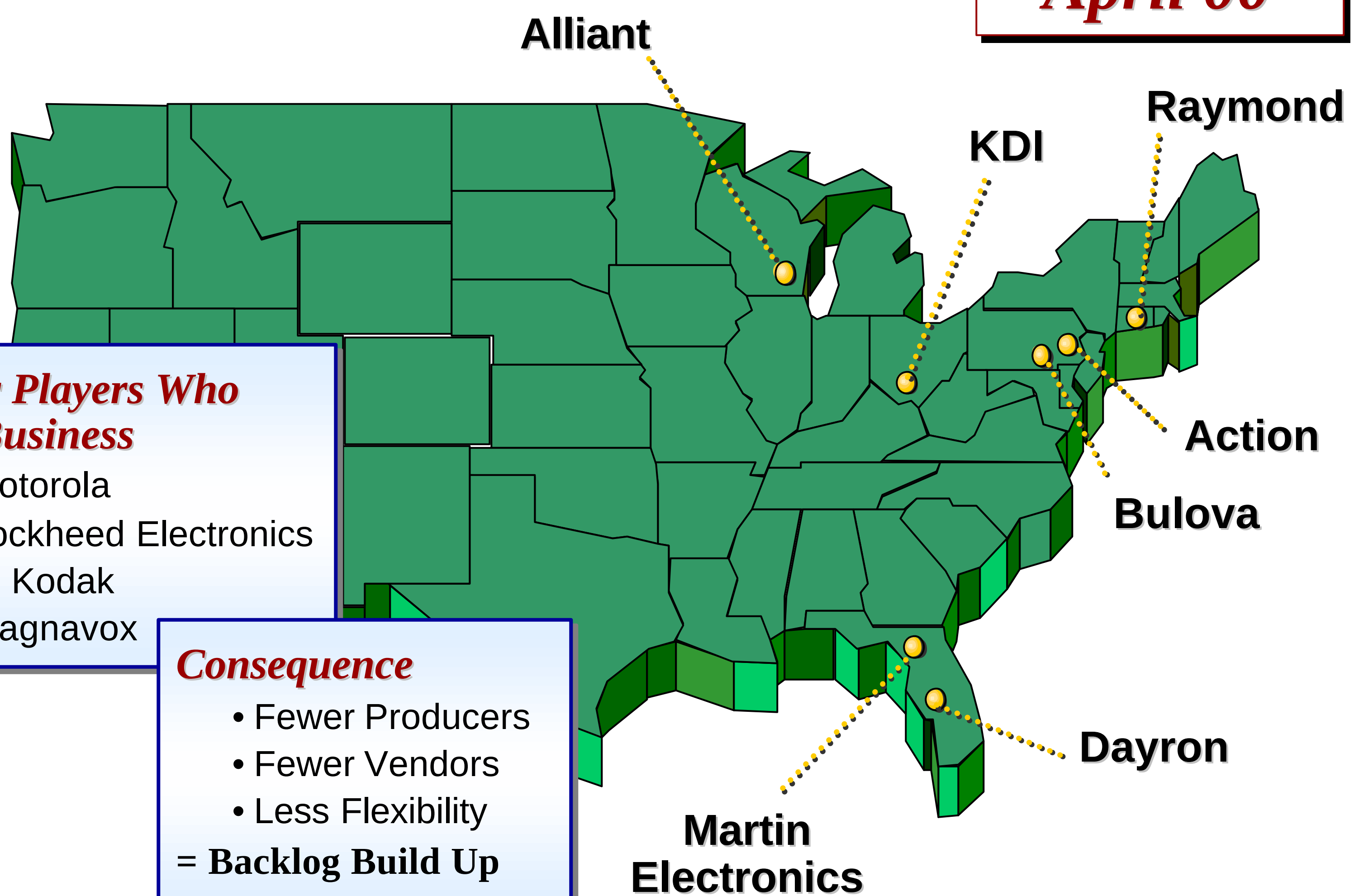
- **Materiel Change Proposal Using Production Dollars**
- **Fuze Stockpile Assessments**
- **EED Initiative**
- **Still Working Fuze Development Issues**
- **Battery Investigation**

Active Conventional Fuze Industrial Base Producers



Active Conventional Fuze Industrial Base

April 00



Major Players Who Left Business

- Motorola
- Lockheed Electronics
- E. Kodak
- Magnavox

Consequence

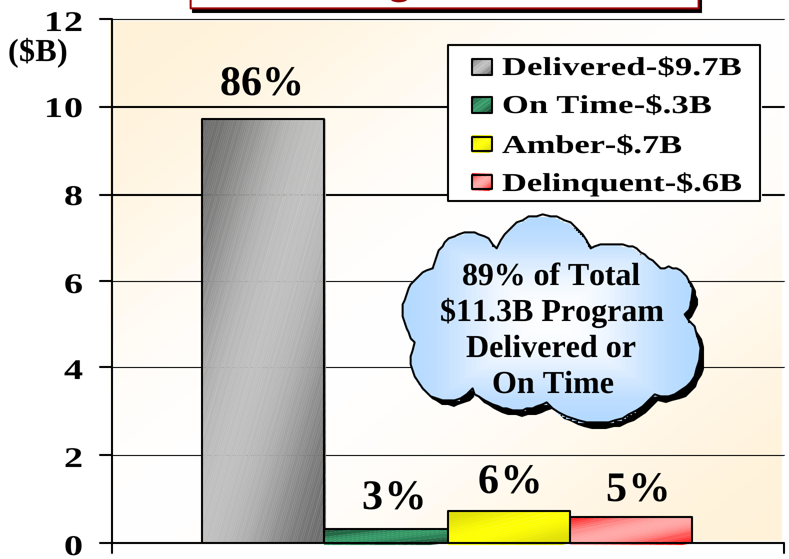
- Fewer Producers
- Fewer Vendors
- Less Flexibility

= **Backlog Build Up**

IOC/SMCA Work In Process (WIP)

FY99 and Earlier Orders: as of 31 Jan 2000

FY91-99 Orders Total Program - $11.303B

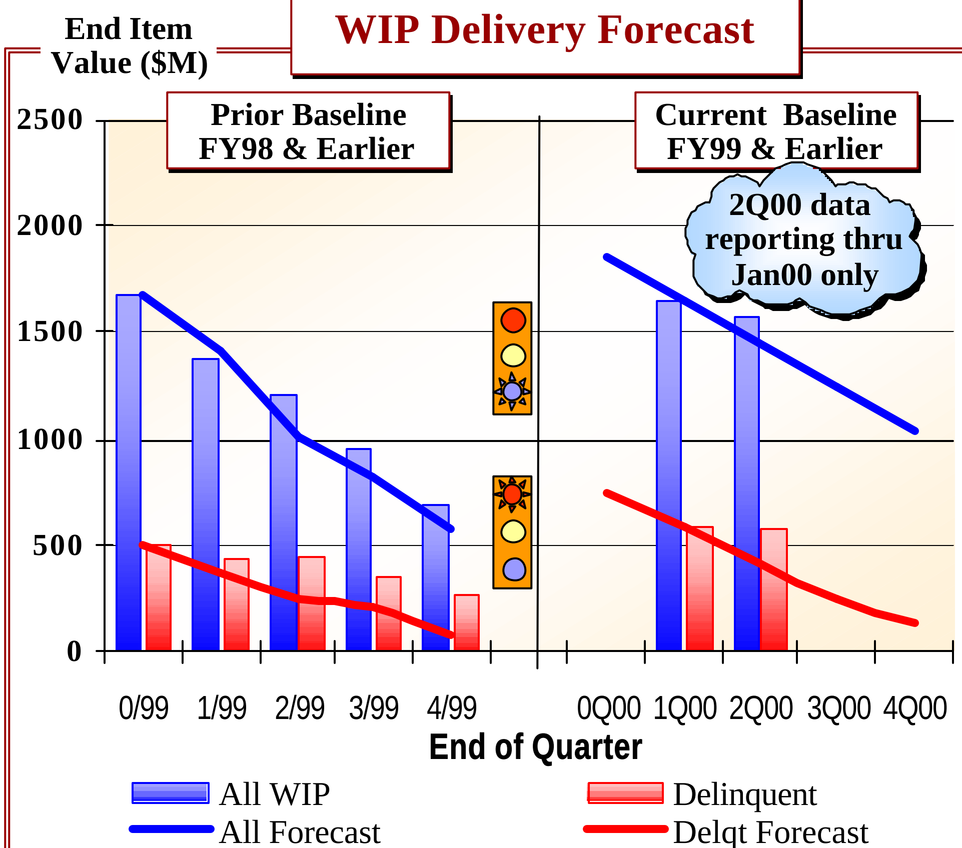


Delinquent Orders		# of	MIPR	Undel
Section	Customers	Orders	Value-$M	Value-$M
Mortars	A,M,N	28	244	165
Fuzes	N,A,AF	9	146	16
Med Cal	A,AF,M	50	165	88
All Others	All	372	576	301
Total		459	1131	570

Delinquent/Red: Deliveries beyond CRDD or FDP, whichever is more stringent

Late/Amber: Green however deliveries scheduled beyond CRDD or FDP whichever is more stringent

WIP Delivery Forecast

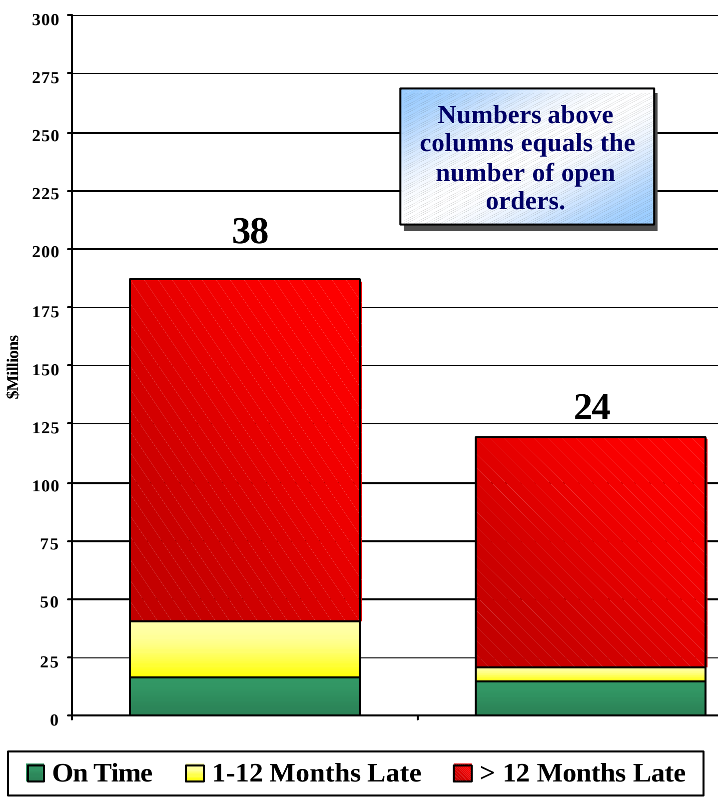


Orders	Green	Amber	Red	Total
1Q99	269	547	432	1248
2Q99	301	451	459	1211
3Q99				
4Q99				

IOC/SMCA Work In Progress (WIP)

FY98 and Earlier Orders: as of 31 Dec 98

Fuzes



Delinquent Orders Section	Customers	# of Orders	MIPR Value-$M	Undel Value-$M
Mortars	A,M,N	29	306	209
Fuzes	All	12	212	99
Med Cal	All	16	89	55
All Others	All	54	177	64
Total		111	784	427

	Principal Delinquent Fuze Orders			
DODIC	Nomen	Value-$M	Undel-$M	Orders
F770	Fz FMU-140	131	24	2
N291	Fz M732A2	52	49	3
N659	Fz MK399	7	6	1
NA01	Fz FMU-153/B	14	13	2

	Orders In Progress			
Orders	Green	Amber	Red	Total
0Q99	20	4	14	38
1Q99	14	2	12	28
2Q99	11	2	11	24

Delivered 14 Orders

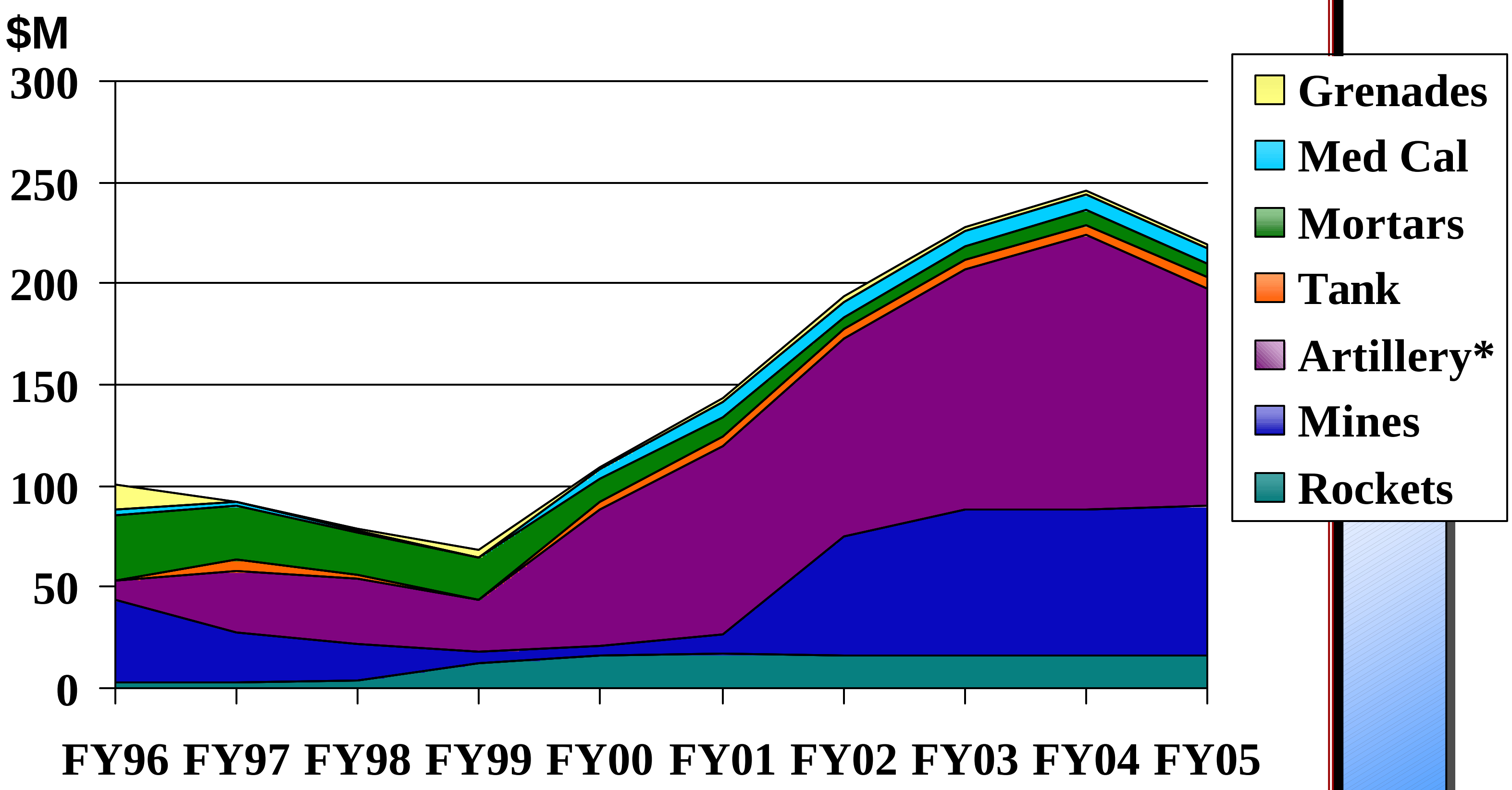
Getting Better
14 of 38 Orders Delivered
Since 7 Oct 98

<u>Delinquent/Red</u> - > 12 months beyond planned production.
<u>Late/Amber</u> - 1-12 months beyond planned production.

Fuze Backlog

Fuze	Problem
M732A2 **FY91 Funded Program** **Now delivered**	**TDP was not ready for Production** **Redesigned ASICs ran into technical & manufacturing difficulties** **Redesigned battery needed qualification** **S&A needed qualification**
MK399/FMU153-B **FY91 Funded Program** **Delivering on adjusted schedule**	**Original contract with REXON had to be terminated** **New contract ran into difficulties getting explosive components from vendor**

Fuze Procurement by Categories: FY96-05

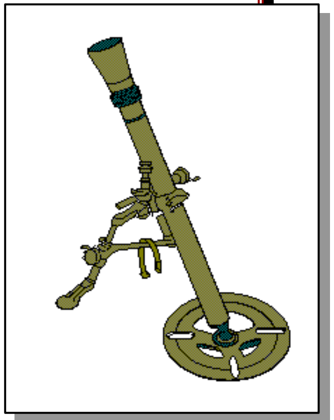


* Includes SADARM TDD and S&A

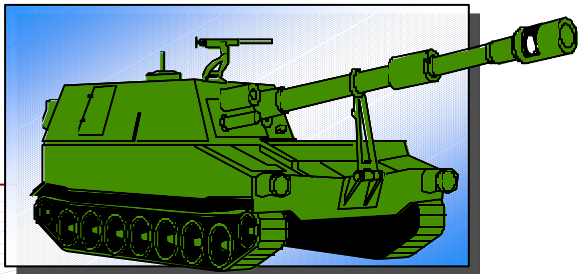
Projected Army Procurement of Ammunition Impacting the Fuze Base

In FY 00-01

- **A. 60mm, 81mm & 120mm Mortar Ammo With:**
  - **Multi-Option Fuze for Mortars M734A1**
  - *Universal Point Detonating Fuze for Mortars XM783*
  - Mechanical Time Fuze for Mortars M772/M776
  - Tng Fuze M781



- **B. Artillery Fuzes**
  - **Electronic Time Fuzes M767E1/M762E1**
  - **Multi-Option Fuze for Arty(MOFA), M782**
- **C. Other**
  - Hydra-70 Rockets
  - Mine Warfare Alternatives



Key Points:

- **ECP initiatives with Electronic Time Fuzes and PD Mortar Fuzes - Army/Contractor initiatives**
- **New technology with MOFA and MOF-M**
- **Fuzes included with mortar and rocket procurements**

Ongoing Fuze Initiatives

M767E1/M762E1 Materiel Change Program

- Older variant producibility - electronic component obsolescence
- Needed limited support for training
- Due to complete June ‘00

M762A1/M767A1 Procurement -

- Outgrowth of health of fuze inventory study
- Intended to replace aging MT fuzes
- Also training component
- Multiyear program following MCP completion

XM783 Universal PD Mortar Fuze

- Replaces M745 and M935
- Used in all mortar calibers

M782 MOFA Procurement

- Multi-year procurement FY99-01
- Expect two producers
- RFP to be released in late April ‘00

Key Points:

- **Joint AFMO / DCS Ammo / PM initiatives to protect base and improve fuze producibility, reliability and performance**
- **Drove increased fuze procurements FY00-05**
- **Potential to restore health in fuze base**
- **EED contract model for future “Production Base” initiatives**

Precision Munitions - Way to the Future?

As We Look At the Recapitalization Cost of Ammunition, There Is Interest In Investing In Precision Munitions

- *Can Provide Significant Warfighting and Logistics Payoffs*
- *Political Sensitivities to Collateral Damage May Increase Focus On Precision Munitions*
- *Need to Look At All Munitions and Fuzing May Need to Lead the Way:*
  - **Low Cost Competent Munitions**
  - **155mm Auto Registration Fuze (or GPS Fuze)**

Closing Comments

With Fewer Fuze Producers, We Continue to Face Greater Pressure to Deliver

We Are Moving Out to Address Concerns You Have Voiced with Respect to Industrial Base

Latest Congressional Language, Section 806 Allows Single Manager for Conventional Ammunition to Restrict Procurement to North American Base

Looking Ahead, Fuze Dollars on an Upswing

The M767A1 Material Change Program, An Investment in Flexible Fuzing

EF Cooper

Staff Engineer

Bulova Technologies LLC

BULOVA TECHNOLOGIES LLC

M767 Material Change

- General upgrade to M762/767 ETF
- Outline
  - Requirements
  - Design changes
  - Results

BULOVA TECHNOLOGIES LLC

M767 Material Change Program

- **Program phases**
  - **Design enhancement**
  - **PPQT**
  - **Qualification**
  - **Production**
- **Topic of presentation is design enhancement phase**

BULOVA® TECHNOLOGIES LLC

M767 M/C Project Team

- No project this significant can be accomplished without a strong team.
- ARDEC and Bulova are working cooperatively under an IPT charter.
- The ARDEC/Bulova team is second to none with regard to artillery and mortar fuzing.

BULOVA TECHNOLOGIES LLC

Bulova M767A1 Core Project Team

- SJ Gurba, V.P. of Military Operations
  - Dave Mengel, M767 Material Change Manager
    - EF Cooper, Staff Engineer
    - Anne Haller, Sr. Contract Administrator
    - John Yoo, Manager R&D
      - Jack Hertzler, Sr. Designer
      - Rick Waller, Sr. Designer
    - Terry Slagle, Sr. Project Engineer
      - Chris Enoch, Engineering/ Config. Mgmt.
    - Mark Loy, Manager QA
      - Kathy Burkhart, Quality Engineer
    - Robin Thomas, Manager Materials Engineering
      - Nick Martyniuk, Materials Engineer
    - Greg Kirchoff, Sr. Electronics Engineer
      - Mike Kimes, Engineering Assistant
    - Tim Wolf, Sr. Electronics Engineer

BULOVA®
TECHNOLOGIES LLC

Program Requirements

- Mechanical
  - Fuze assembly enhancements
  - Fuze robustness enhancements
  - PD function enhancement
  - Improve waterproofness
  - Improve button retainer

BULOVA® TECHNOLOGIES LLC

Fuze Assembly Enhancement

- Surface Mount Crystals
- Encapsulation
- ESD Shield
- Shield Cap
- Fuze Height

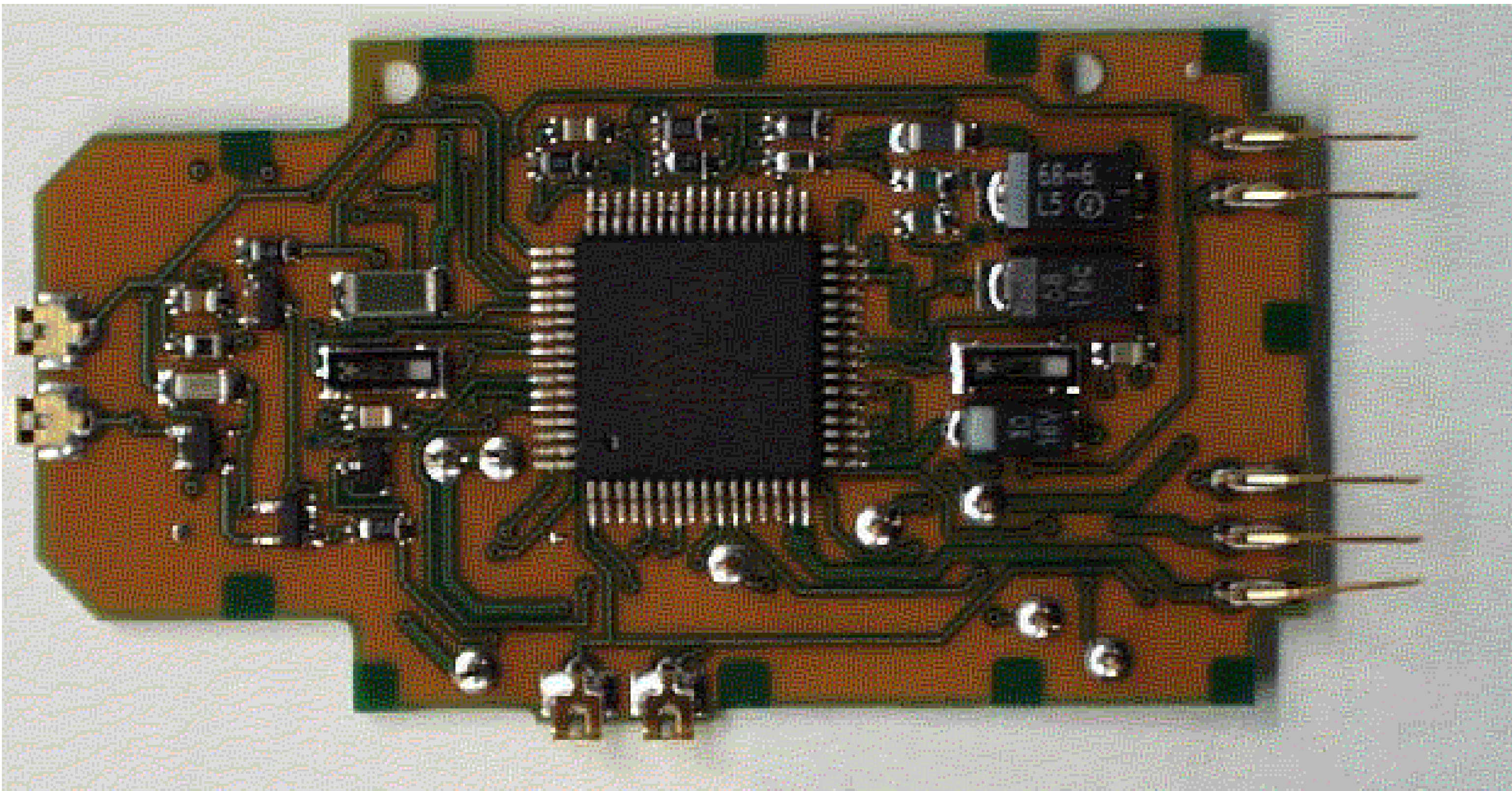
BULOVA®
TECHNOLOGIES LLC

Surface Mount Crystals

- Replace the existing leaded crystal with SMT part
- Developed a new package
- Proved design through environmental and ballistic testing

BULOVA® TECHNOLOGIES LLC

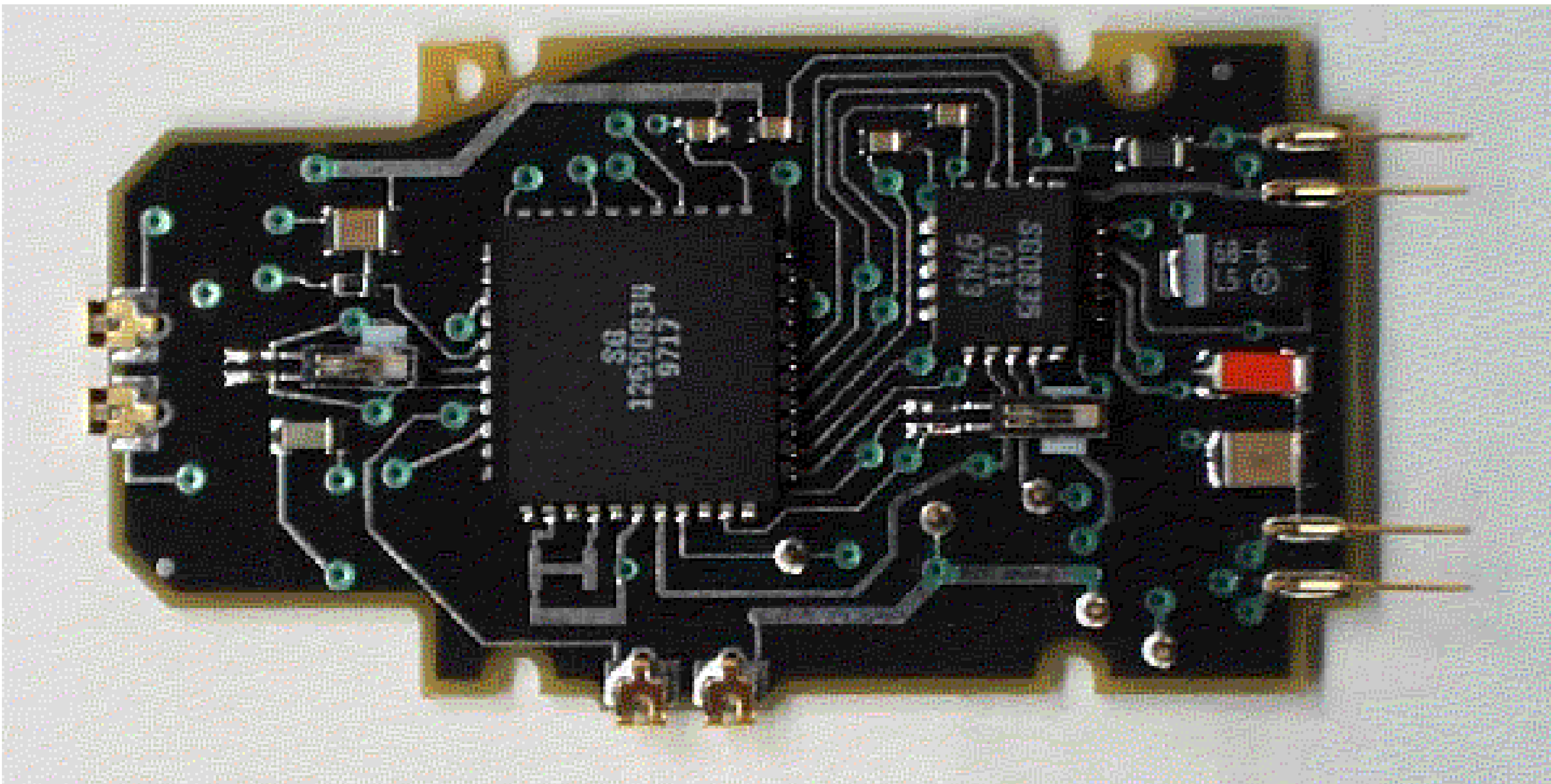
M767A1/762A1



COOPER 04/00

BULOVA®
TECHNOLOGIES LLC

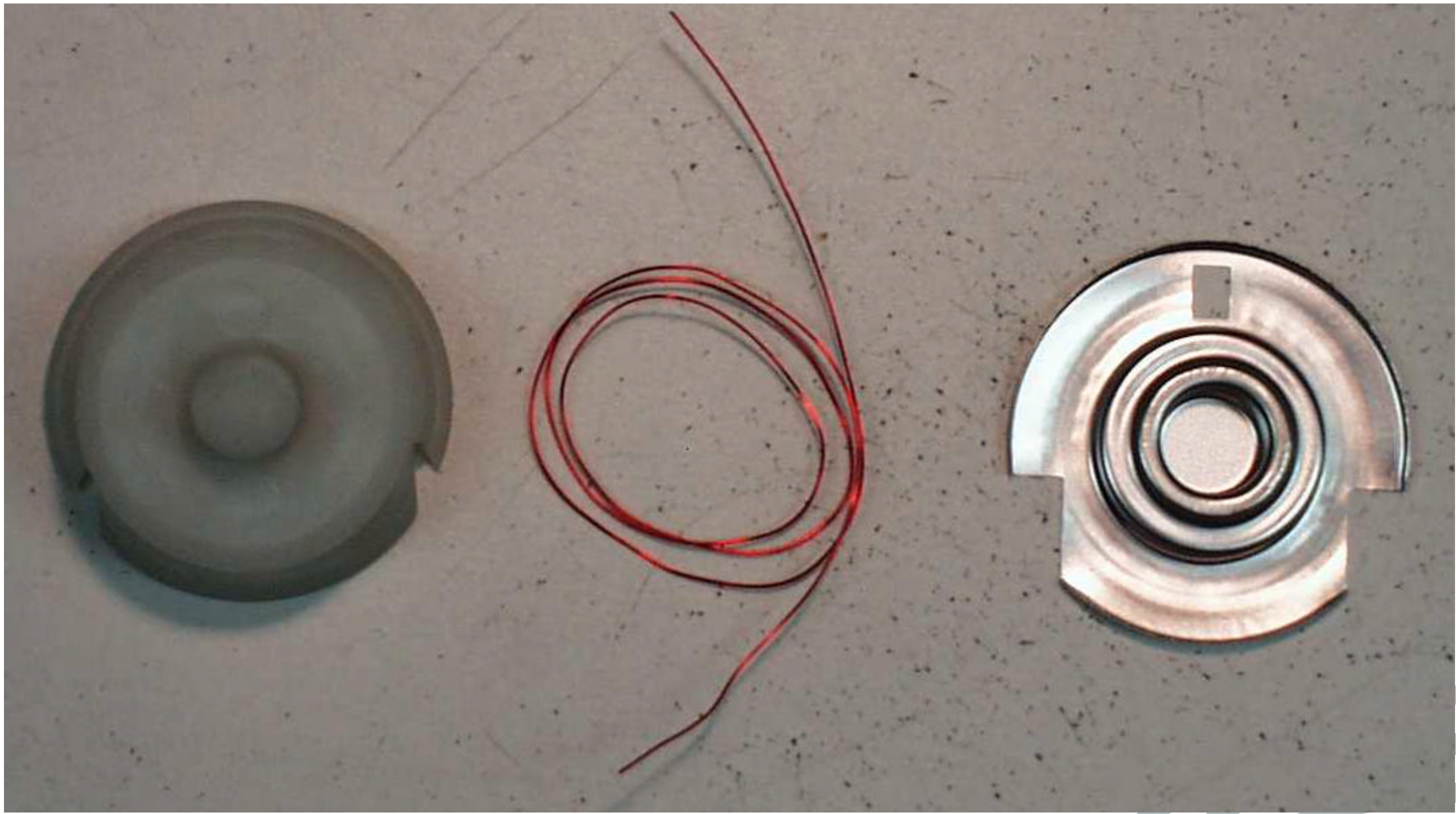
M767/762



COOPER 04/00

BULOVA®
TECHNOLOGIES LLC

ESD Shield



COOPER 04/00

BULOVA®
TECHNOLOGIES LLC

Shield Cap

BULOVA® TECHNOLOGIES LLC

Robustness Enhancement

- S&A redesign
- Battery connection
- End cap attachment
- LCD lens/fuze housing

NAVAL AIR WARFARE CENTER
WEAPONS DIVISION

FUZING OVERVIEW

Randall D. Cope
Head, Ordnance Technology Office
Code 478C00D, China Lake

NAWCWPNS Mission

- Navy's full-spectrum RDT&E and In-Service Engineering center
  - Weapon systems associated with air warfare
  - Missiles and missile subsystems
  - Aircraft weapons integration
  - Assigned airborne electronic warfare system
  - Maintain and operate the air, land and sea Naval Western Test Range Complex

Fuze Technical Role

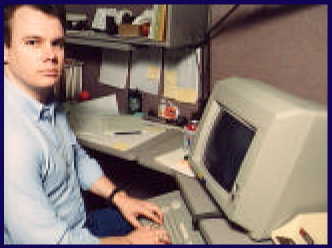
- Designated Navy leadership For Missile and Free-Fall Weapon Fuzing
  - Technology Principle
  - Technical Design Agent
  - Design Agent
  - In-Service Engineering
- NAVAIR Competency Leader for Ordnance Sections

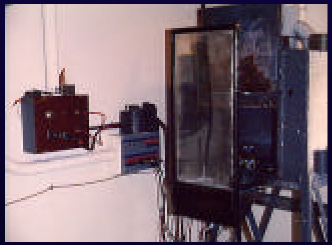
Technical Responsibility

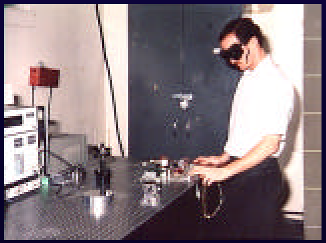
- Technology Planning
- Fuze Technology Development
- Competency leader for All NAVAIR Ordnance Sections
- In-service Engineering on All Free-fall Weapons
- Technical Direction Agent for Standard Missile Fuzing
- Design Agent for SLAM ER Ordnance Section (Warhead, Fuze, and Initiation System)
- Design Agent for Tactical Tomahawk Penetration Variant
- Ordnance Hazard Evaluation Board (IM Evaluation)
- Member Weapon System Explosive Safety Review Board

Ordnance Capabilities

- Ordnance Section Design, Test, Evaluation and In-Service Engineering
- Design of Mechanical and Electronic Components for Explosive / Pyrotechnic Safety Systems
- Testing and Evaluation of Explosive Components Containing Primary and Secondary Explosives
- Modeling of Mechanical and Explosive Events
- Advanced Initiation Testing and Evaluation
- Ballistic Evaluation of Aircraft Guns and Ammunition
- Thermal Evaluation of Ordnance Components
- Very Large Explosive Detonation Tests (up to 500,000 lbs)







Fuzes In The Fleet

Missile S-A Devices In Use

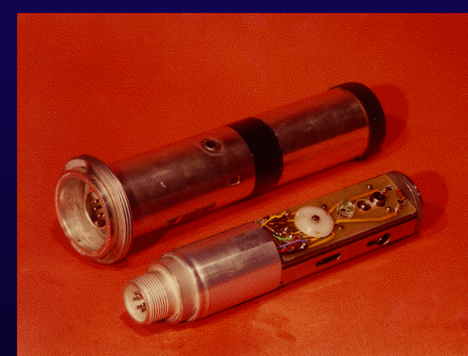
HARM MISSILE FUZE,
FMU-111/B

**TOMAHAWK BLK 3 FUZE,
FMU-148/B**

STANDARD MISSILE S-A,
MK 54 MOD 0

PHOENIX MISSILE FUZE, FSU-10/A

SPARROW MISSILE S-A, MK-33



SIDEWINDER MISSILE FUZE,
MK-13 MOD 2

Free-Fall Weapon Fuzes In Use

FMU-139 A/B, Electronic Bomb Fuze

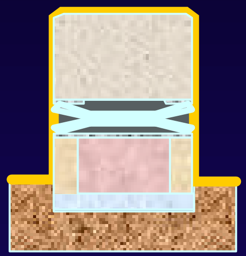
DSU-33B/B Proximity Sensor

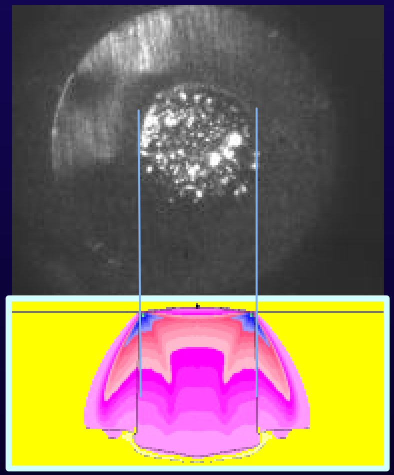
FMU-143, Electronic Bomb Fuze

FMU-140 /B, Dispenser Proximity Fuze

New Fuze Developments

Low Energy EFI



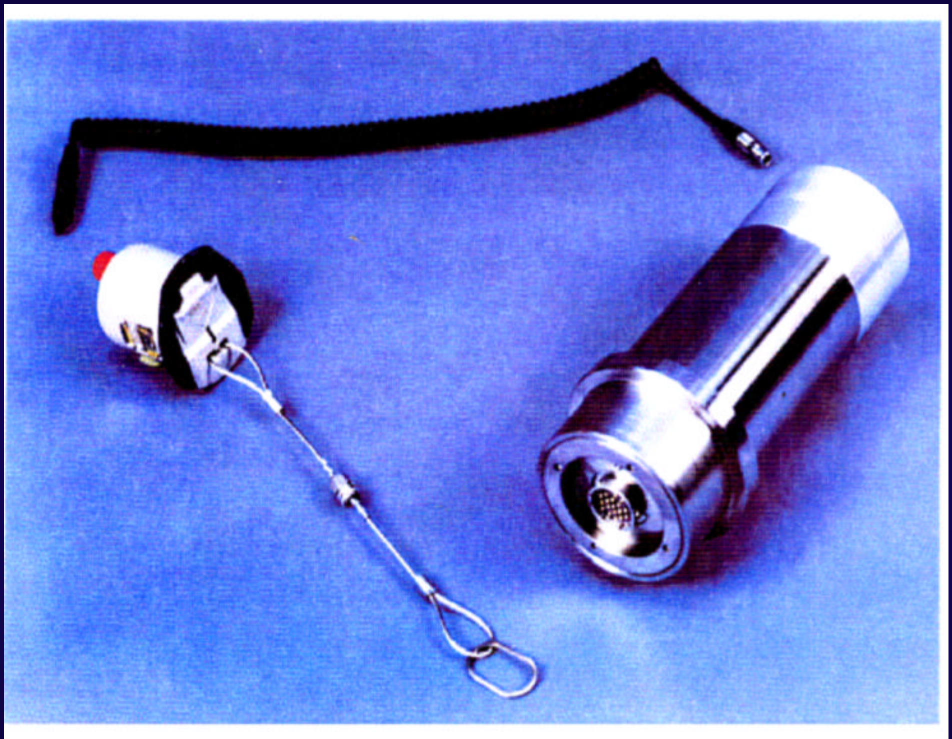


Description:
- A low energy EFI Detonator
    - Fully Qualified
    - In Production

Major Accomplishments:
- Taguchi Matrix used for design optimization
- Qualified design using proposed MIL-STD 331 Test G1
- Used in Multiple Systems

Future Plans:
- Improve design
    - Reduced cost
    - Increased output

Hard Target Smart Fuze



<u>Description:</u> Multi-platform penetrator fuze with programmable operating modes. Air Force is lead service, Navy will use in GBU-24 and Tomahawk TTPV.

<u>Major Accomplishments</u>:

- **Navy safety and performance requirements implemented into baseline**

<u>Future Plans</u>:

- **Continue to participate with the team insuring that Navy requirements are met**

FMU-155/B (SLAM ER)

Description:

- Pneumatic Armed (Differential Pressure)
- 3 Detonation Delay Selections (Pyrotechnic)
- Evolved From FMU-109/B

Major Accomplishments:

- Qualified to SLAM ER and Block 3 Tomahawk Environments
- Demonstrated Penetration Capability
- Currently in LRIP

Future Plans:

- Full Rate Release Expected this Spring

FMU-152 JOINT PROGRAMMABLE FUZE (JPF)

Description:

In-flight cockpit selection, multi-function and multi-delay arming and fuzing functions with hardened target penetration capability. Air Force is lead service with Navy involvement.

Major Accomplishments:

- Test Sets Fabricated
- Operational Evaluation Tests Completed
- First Article Testing to Start in May

Future Plans:

- First Article Flight Tests
- LRIP in FY-00 through FY01
- Monitor production of projected option quantities (FY01-FY09 - 24,824 units)

RAM MK-20 Mod 2 AOTD

Description:

- Active Optical Target Detector
- Derivative of Sidewinder DSU-15A/B AOTD
- Redesign of MK-20 Mod 1 with improved low altitude performance

Major Accomplishments:

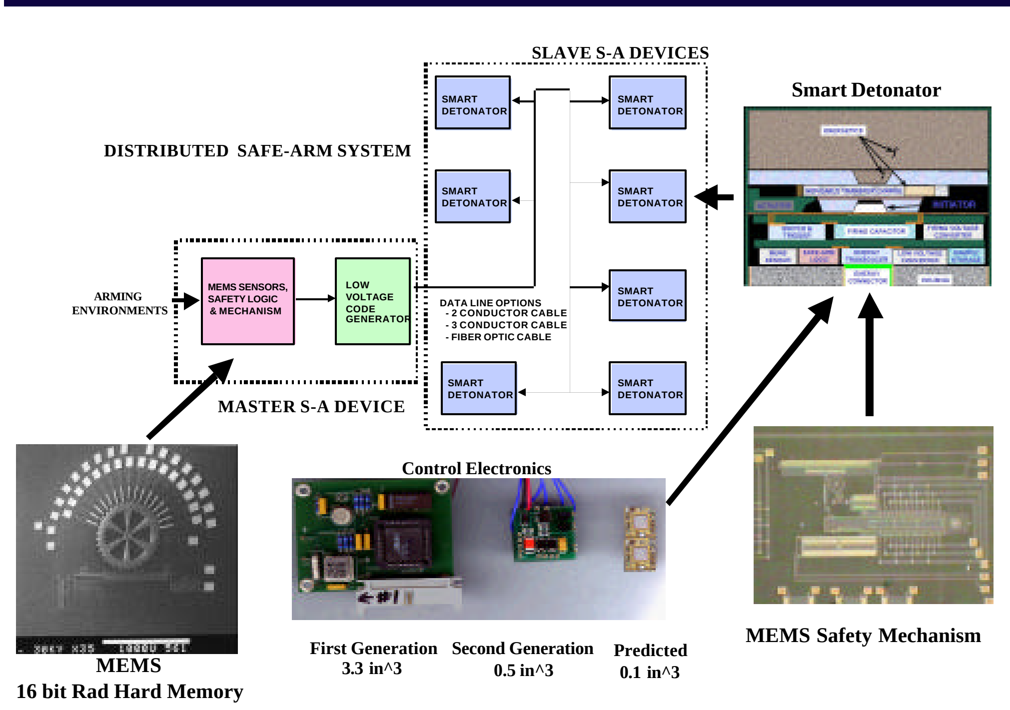
- Successfully completed Operation Testing

Future Plans:

- RAM starting full rate production

Fuze Technology Programs

MEMS-Based Distributed S-A



Description:

- Master control unit senses arming environments per MIL-STD-1316, then generates unique arming commands to selected “slave” detonators
- Each det contains MEMS mechanical locks to prevent inadvertent arming
- Up to “n” dets distributed within system to enhance performance

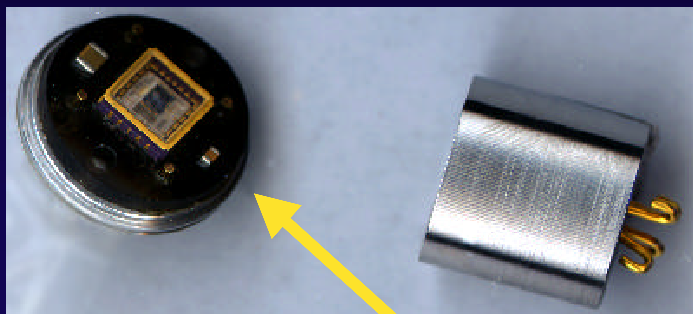
Major Accomplishments:

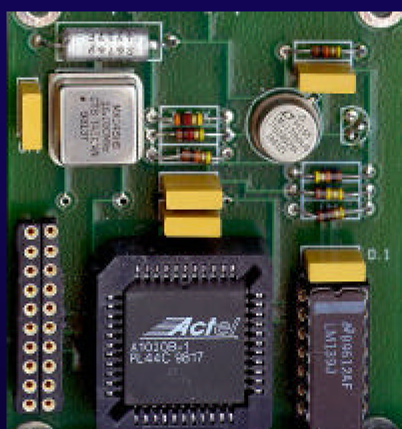
- Safety analysis of arming commands
- Detonator Modeling
- MEMS lock/interrupter design
- Initial Explosive Tests
- Electronic Design

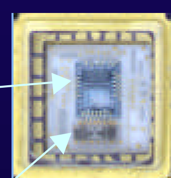
Future Plans:

- Complete design
- Demonstrate Feasibility

Advanced Fuze Contact Device







<u>Description:</u> **Improve FCD technology**

- **Improved response time**
- **Greater sensitivity to off-axis hits**
- **Decreased per unit cost**

<u>Major Accomplishments:</u>

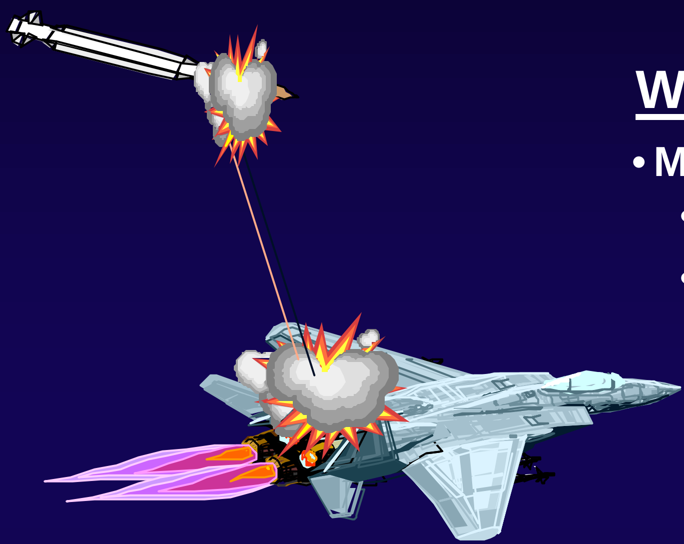
- **End game modeling**
- **Baseline FCD circuit**

<u>Demonstrated:</u>

- **Alternative Sense Elements**
- **Variable Time Delay**
- **Adjustable Thresholds**

ANTI-AIR GIF TECHNOLOGY

Precision Intercept



WHAT ARE WE TRYING TO DO

- Maximize Lethality for Broad Spectrum of Targets
  - Control the Dynamic Intercept Geometry
  - Provide Warhead Mode Select Logic

BY WHEN

- Missile Manager Architecture FY00
- Control Algorithms Set FY01
- Assess Lethality Effectiveness FY02

WHAT MAKES IT POSSIBLE

- High Range Resolution Sensors
  - Reduce Measurements Errors
  - Increase Aimpoint Resolution
- Long Range Predictive Capability
- Modern Processing Calculation Speed

WHAT DIFFERENCE WILL IT MAKE

- Greater Probability of Kill over Wider Encounter Conditions & Target Types
- Offers Reduced Weapon Size/Weight with Smaller Warhead

Anti-Surface TDD Technology

What Are We Trying To Do

- Demonstrate Millimeter Wave Technology For Direct Target Detection Of Masted Enemy Air Defense Targets
- Develop Representative Tactical TDD Design

What Makes You Think You Can Do It

- Demonstrated Sensor Technologies
- Increased Signal Processing Capability

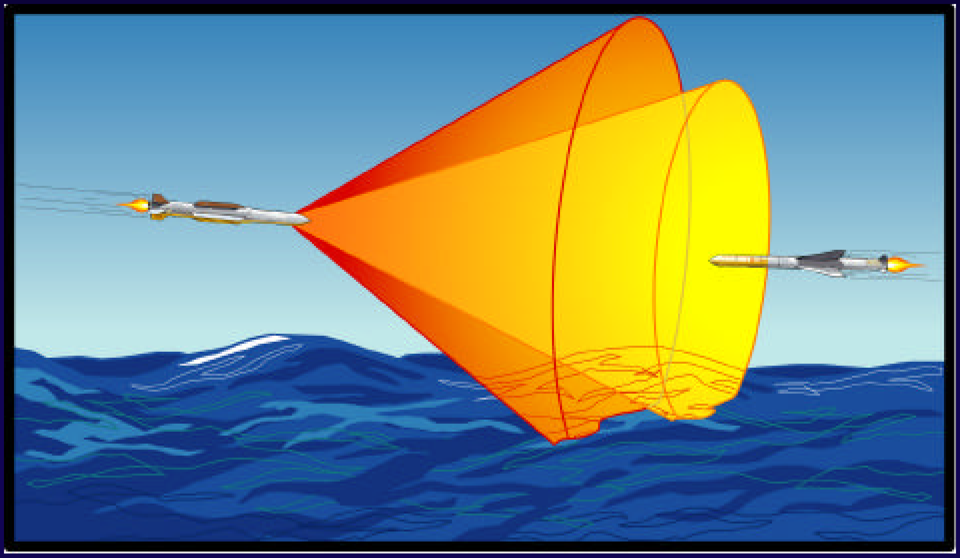
What Difference Will It Make

- Increased Probability of Kill
- Strike Applications

Short Pulse Laser TDD

What Are We Trying to Do

- Provide High Lethality Against Sea Skimming Supersonic Targets
- Extend the Operation Capability to Include:
  - All Aspect Encounter
  - Adverse Weather
  - Increased Target Sets
  - Low Altitude Severe Clutter Operation



What Makes You Think You Can Do It

- High Peak Power Sub-nanosecond Laser Transmitters
  - Large Target to Aerosol Backscatter Ratio
- High Bandwidth / High Gain Receivers
  - Increased Signal to Noise Ratio

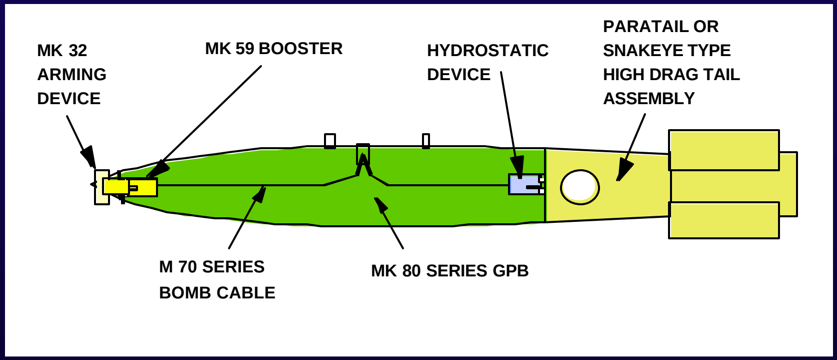
By When

- Sensor Concept Capability Can Be Demonstrated By 2002

What Difference Will It Make

- Increased Probability of Kill
  - Adverse Environmental Conditions
  - All Aspect Encounter

Hydrostatic Device



Description:

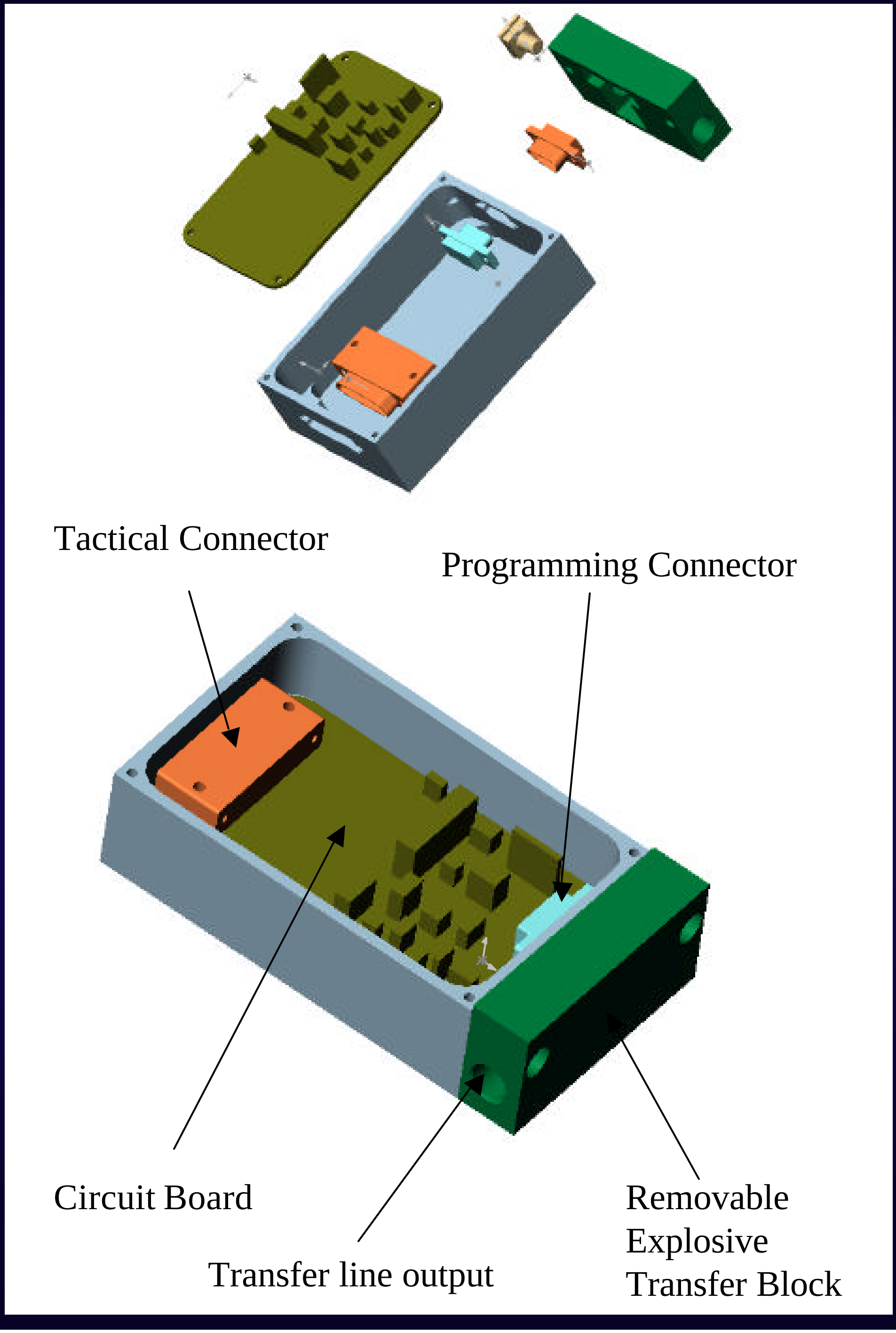
MK-80 Series GPB Equipped with Hydrostatic Sensor Provides Low Cost Effective Depth Bomb Capability

Major Accomplishments:

- ONR Funded Risk Reduction Phase
- CRADA with KAMAN for Demo Units

Future Plans:

- E&MD Start in 01,
- Production Start in 03



JAMIS FTSA

Description: Joint Advanced Missile Instrumentation System, Flight Termination Safe-Arm

- **Programmable performance for multiple applications**
- **Low Cost**

Major Accomplishments:

- **Spec Nearing Completion**
- **Electrical Design Nearing Completion**
- **Electrical Volume Study Complete**
- **Fireset Studies Complete**

Future Plans:

- **Qual Plan in Process**
- **Qualification in 2002**

Summary

- Navy Lead for Missile and Free-Fall Weapons Fuzing
- Supporting
  - ➡ Technology
    - ➡ Development
      - ➡ Production
        - ➡ In-Service

Twin-Screw Processing of GEM Gun Propellant

Twin-Screw Processing of GEM Gun Propellant

M. Gallant, W. Newton, S. Johnson, S. Prickett and C. Murphy (9420)

D. Kalyon, A. Lawal, and S. Railkar
HfMI/Stevens Inst. of Technology

12 Apr 2000

44th Annual Fuze Conference & Munitions Manufacturing & Technology Symposium
Pleasanton, CA

Affordable Green Energetic Materials (GEM)

- High Performance, Minimum Life-Cycle Environmental Impact Materials
- Meet Naval Surface Fire Support (NSFS) Extended-Range Guided Munition (ERGM) 5-inch Projectile Mission Requirements
- Warhead, Rocket Motor, and Gun Propellant
- Manufactured at Lower Total Life Cycle Cost Than Current Materials

2

Develop a New Continuously Processed Gun Propellant

Accomplished the First Five Goals

- Devise Feeding Method for Virgin Polymer
- Melt, Mix & Extrude Quality Strands Using a Twin-Screw Extruder
- Design Take-Away Equipment & Integrate Bofors Cutter
- Rheological Characterization & Die Design
- Produce 200 lbs. Test Quantity
- Develop Recycling Scheme Including Reduction, Feeding, Melting, & Extruding

3

Live Processing Trials

Single Strand Batch LOVA Die

- Conserve Polymer - Run at Very Low Throughput
- Design Screw for Vacuum Processing (Degree of Fill)
- Minimize Viscous Heating in Solids Mixing Section
- Evaluate Effect of Process Parameters on Extrudate Quality
- (show video)

4

Twin-Screw Processing of GEM Gun Propellant

Feed Locations

Side View of ZSK Set-up for GEM Gun Propellant

NAVSEA INDIAN HEAD

Processing Conditions Screening Study

Four-Fold Objective

- Screw Design for Vacuum Processing (Low Throughput)
  - Surging: Function of Screw Fill, Geometry, and RPM
  - Screw Fill: Throughput and RPM
- Screw Design to Minimize Viscous Heating (VDH)
  - Function of Screw Fill, Screw Geometry, and Barrel temperature
- Melting & Mixing Efficiencies
  - Temperature, Throughput & RPM Effects
- Extent to Which Conditions Affect Extrudate Quality

NAVSEA INDIAN HEAD

Rheology Drives the Train

Indian Head is Building an In-House Capability

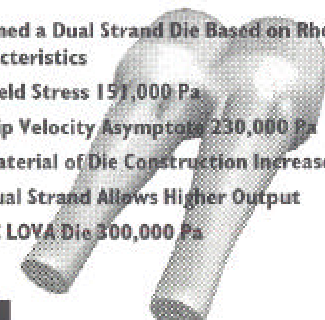
- Modern Energetic Materials Increasingly Non-Newtonian
- NSWC Characterized Rheology Using Capillary Dies (Dr. Prickett)
  - Various Diameters and Lengths
  - 2" Press with Vacuum & Temperature Control (1.5 kg)
- Purchasing a Laboratory Scale Capillary Rheometer (100 g)
- Evaluating Poly3D™ – Mold & Die Design Software (Code 590)

NAVSEA INDIAN HEAD

Smart Die Design

Drs. Kalyon, Railkar, & Lawal, HfMI/SIT

- Designed a Dual Strand Die Based on Rheological Characteristics
  - Yield Stress 157,000 Pa
  - Slip Velocity Asymptote 230,000 Pa
  - Material of Die Construction Increases the Ceiling
  - Dual Strand Allows Higher Output
- NSWC LOVA Die 300,000 Pa



NAVSEA INDIAN HEAD

Twin-Screw Processing of GEM Gun Propellant

Show vu-graphs of design, modeling and hardware

- (vu-graphs of Modeling)
- (vu-graph of design sketch)
- (vu-graphs of finished design)

Die Implementation

Wrong Assumptions & Poor Conventional Wisdom

- Keep Strand as Cold as Practical: Chilled Water in Take-Away
  - Ensure Best Perforation Formation
  - Best for Cutting
- Mix at Low Barrel Temperatures
- Extrude at Low Die Temperature: Air Cool Extrudate

Successful Extrusion

No Die Air-conditioning for Extrudate

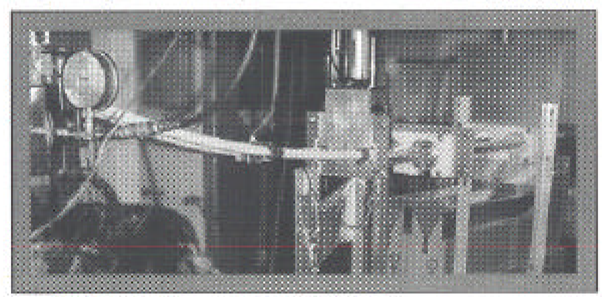
Raised Die Temperature (+15°F)

Independent Heat Control for Die Zone

Location of Controlling Thermocouple

Strand Handling x 2

Designed by Bill Newton (father of the Newtomatic)



Twin-Screw Processing of GEM Gun Propellant

Successful Take-away

- Initial Cut and Remote Capture
- Warm Water: Issue is Strand Hardness
- Best to Pelletize On-line

NAVSEA

13

Conclusion

- Ingredients to Grains in One Facility
  - Continuous
  - Robust Design
  - On-line Pelletizing Possible
- No Solvents
- Rheological Characterization Critical for Extrusion Success
- Dual Strand Die - Higher Overall Throughput Possible
- Vacuum Processing at Very Low Throughput
- Excellent Dimensional Stability – 0.600" dia. ± 0.0042"
- Gun Firings Last Spring

NAVSEA

14

GIF Performance and Implementation Issues in Air Defense Missions

April 12, 2000

Presented At:

NDIA 44th Annual Fuze Conference “Flexibility in Fuzing”

By:

Mr. Milton E. (Gene) Henderson, Jr.

US Army Aviation and Missile Command

Mr. Graham C. Killough

KBM Enterprises, Inc.

Topics

- **Purpose**
- **Definitions and Data Requirements**
- **LED Characteristics**
- **Baseline GIF Architecture**
- **Baseline GIF Performance Assessment**
- **State Estimation Performance / Sensitivity Analysis**
- **Baseline GIF Revision**
- **Conclusions**

Purpose

- **The Study Purpose is the Investigation of the Performance of Guidance Integrated Fuzing under Realistic Conditions Against Cruise Missiles and TBM Threats Through:**
  - High Fidelity Modeling of an Active RF Tracking and Guidance System
  - Utilization of Advanced State Estimation Techniques, Including but not Limited to Kalman Filtering
  - Performance Assessment with a Variety of Isotropic and Aimed Lethality Enhancement Devices (LED).
- **The Study Goal is to Understand and Quantify the System and LED Performance Drivers for Guidance Integrated Fuzing:**

System:

- **Data Rate**
- **Measurement Accuracy**
- **Engagement Conditions**
- **Data Filtering / State Estimation**

LED:

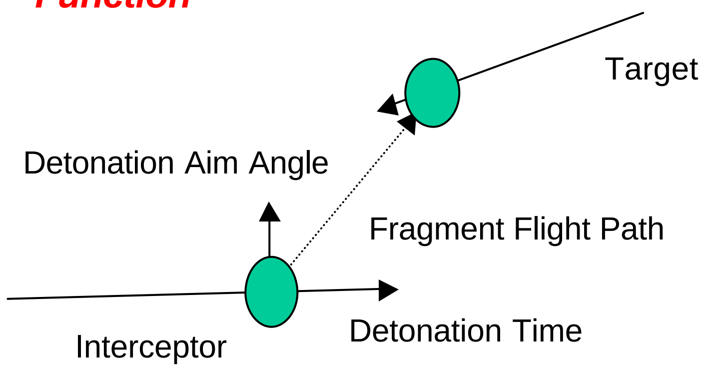
- **Maximum Performance**
- **Region of Acceptable Performance**
- **Sensitivity to Fuzing Errors**

An Optimum GIF Implementation Should Pay Off in Decreased System Mass and Increased Lethality

GIF Definitions and Data Requirements

A Guidance Integrated Fuze (GIF) is an Algorithm that Utilizes on Board Guidance Data as Input to an Estimate of the Optimal Time (and Direction) for the Detonation of a LED.

Function



Detonation Time is a Function of Closing Velocity, Miss Distance and Fragment Velocity

Detonation Aim Angle is a Function of the Components of the Miss Distance Vector

Data Flow

Inputs

- **System Time (Data Time)**
- **Range to Target***
- **Boresight Angles***

System Constants

- **Data Rate**
- **Time Lag**

Outputs

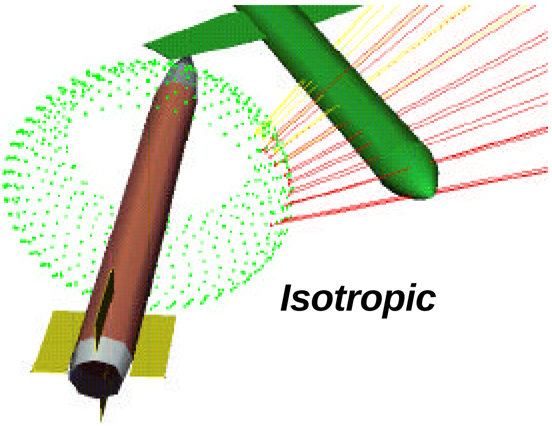
- **Detonation Time Estimate**
- **Detonation Angle Estimate**

Measures of Merit

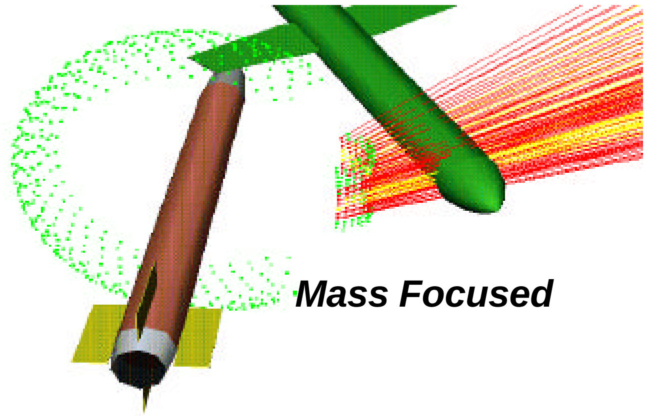
- **Time of Detonation Accuracy**
- **Aim Angle Accuracy**
- **Time Before Detonation of "Good" Fuzing Estimate**

** Can Be A Vector Describing Target Position. Either Type Must be Converted to a Warhead Frame of Reference*

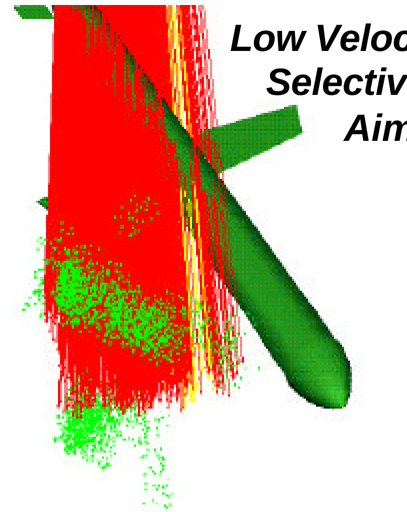
LED Characteristics



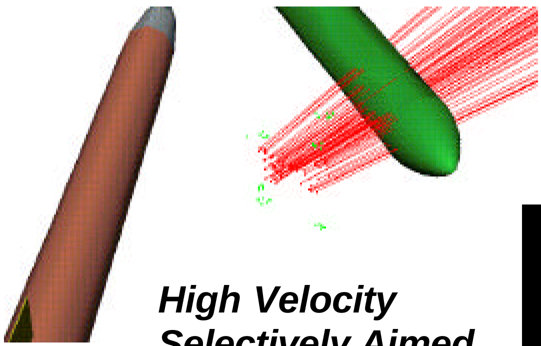
Isotropic



Mass Focused



Low Velocity Selectively Aimed



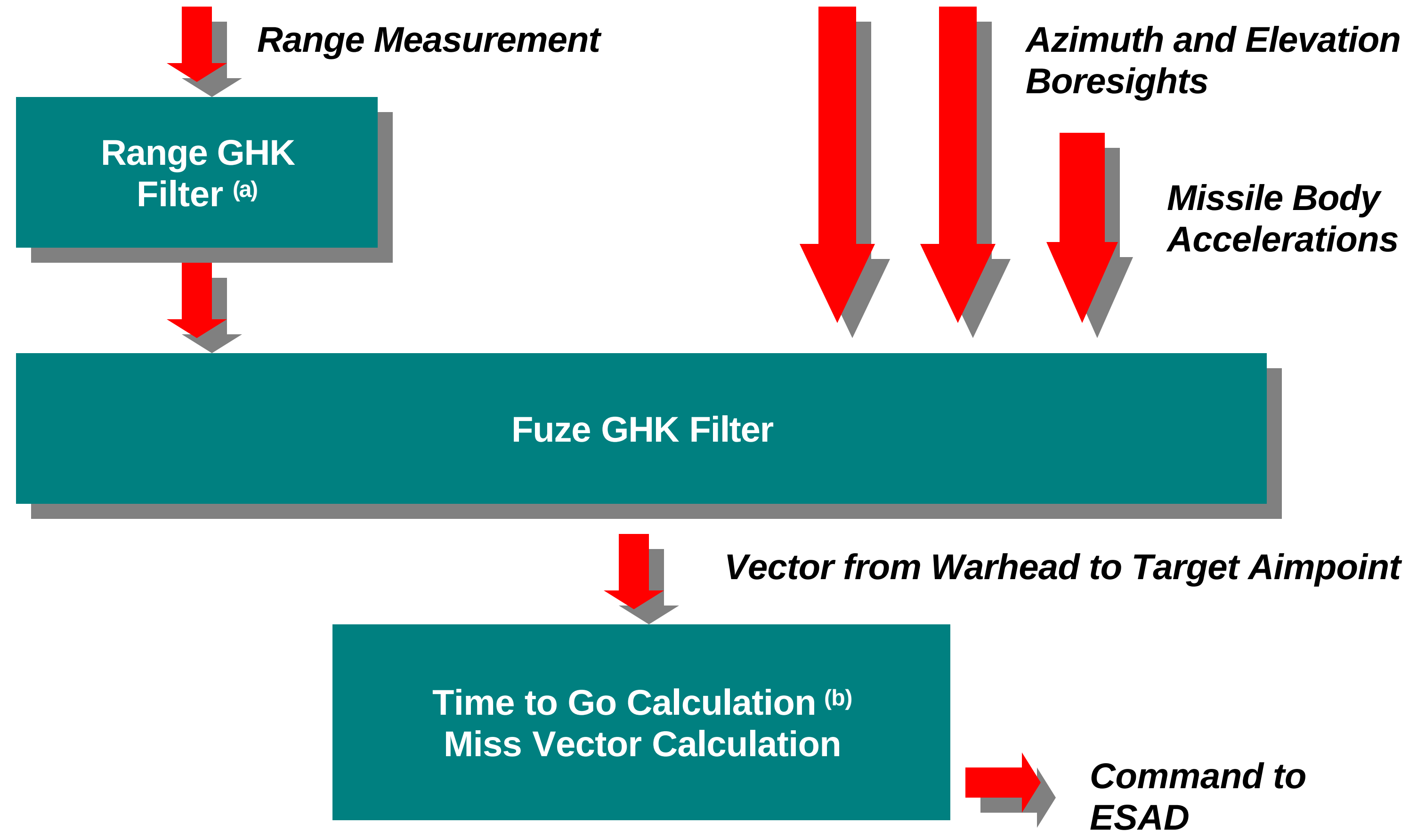
High Velocity Selectively Aimed

LED Characteristics

Warhead	*Mass (Kg)*	*Number of Projectiles / Projectile Mass (g)*	*Average Ejection Velocity (m/s)*	*Longitudinal Ejection Angle (deg)*	*Radial Extent of Aimed Section (deg)*
Isotropic	≅70	685 / 45	1675	≅60	N/A
Mass Focused	≅70	690 / 45	1955	≅20	≅20
Low Velocity Selectively Aimed	≅70	4064 / 13	50	≅1	≅55
High Velocity Selectively Aimed	≅46	851 / 13	1345	≅1	≅30

Baseline GIF Architecture

Guidance System



(a) Only Used to Initialize the Fuze GHK Filter

(b) Only the Longitudinal Component is used

Baseline GIF Performance Assessment

Engagement Altitude

"Slow" TBM Engagements

LED Concept	Aimed Pattern Width (deg)	Low	Medium - Low	Medium - High	High
Isotropic	N/A				
Mass-Focused	20				
High-Velocity	55				
Low-Velocity	30				

"Fast" TBM Engagements

LED Concept	Aimed Pattern Width (deg)	Low	Medium - Low	Medium - High	High
Isotropic	N/A				
Mass-Focused	20				
High-Velocity	55				
Low-Velocity	30				

Cruise Missile Engagements

LED Concept	Aimed Pattern Width (deg)	Low	Medium	High
Isotropic	N/A			
Mass-Focused	20			
High-Velocity	55			
Low-Velocity	30			

Capable **Marginal** **Not Capable**

State Estimation Techniques

Alpha Beta

Update Equations

$$\hat{x} = \hat{x}_n + a(y - \hat{x}_n)$$

$$\dot{\hat{x}} = \dot{\hat{x}}_p - \frac{b}{T}(y - \hat{x}_n)$$

Prediction Equation

$$\hat{x}_n = \hat{x} - \dot{\hat{x}}T$$

GHK

Update Equations

$$\hat{x} = \hat{x}_n + g(y - \hat{x}_n)$$

$$\dot{\hat{x}} = \dot{\hat{x}}_n - \frac{h}{T}(y - \hat{x}_n)$$

$$\ddot{\hat{x}} = \ddot{\hat{x}}_n - \frac{2k}{T^2}(y - \hat{x}_n)$$

Prediction Equations

$$\hat{x}_n = \hat{x} - (T\dot{\hat{x}} + \frac{1}{2}T^2\ddot{\hat{x}})$$

$$\dot{\hat{x}}_n = \dot{\hat{x}} - T\ddot{\hat{x}}$$

$$\ddot{\hat{x}}_n = \ddot{\hat{x}}$$

GHKI (same as GHK w/ following additions)

Update Equations

$$\dddot{\hat{x}} = \dddot{\hat{x}}_n - \frac{6i}{T^3}(y - \hat{x}_n)$$

Prediction Equations

$$\hat{x}_n = \hat{x} - (T\dot{\hat{x}} + \frac{1}{2}T^2\ddot{\hat{x}} + \frac{1}{3}T^3\dddot{\hat{x}})$$

$$\dot{\hat{x}}_n = \dot{\hat{x}} - (T\ddot{\hat{x}} + \frac{1}{2}T^2\dddot{\hat{x}})$$

$$\ddot{\hat{x}}_n = \ddot{\hat{x}} - T\dddot{\hat{x}}$$

$$\dddot{\hat{x}}_n = \dddot{\hat{x}}$$

Kalman

Estimator Equation

$$\hat{x} = A\hat{x}_p + K(y - CA\hat{x}_p)$$

Filter Gain

$$K = P_1C^T(CP_1C^T + R)^{-1}$$

where $P_1 = AP_pA^T + Q_p$

Error Covariance Equation

$$P = P_1 - KCP_1$$

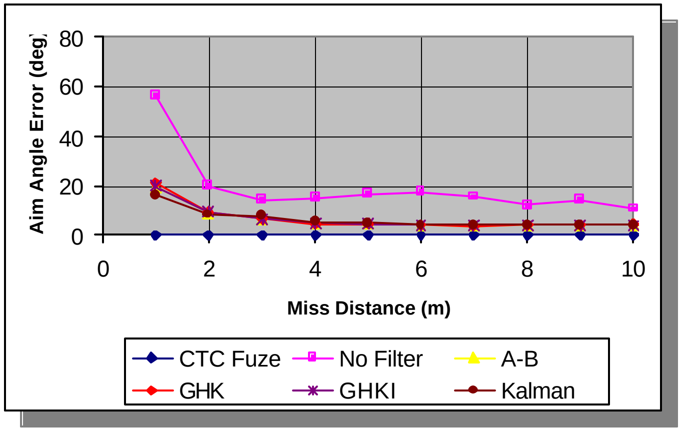
The Four State Estimation Techniques were Integrated into the RDEC Lethality End Game Simulation (RLEGS) Engagement Generator - Allowing Parametric Assessment of Performance and Sensitivities. Study Variables Included:

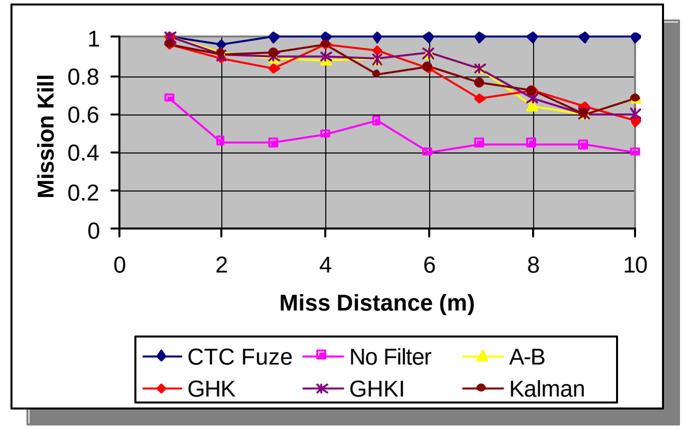
- **Sensor Error (Angle and Range)**
- **Threat - Engagement Conditions**
- **GIF Data Rate**
- **GIF Blind Range**

Parametric Performance of the State Estimation Techniques

Cruise Missile Engagements

- **Little Differentiation in Filter Performance**
- **CTC Fuze Illustrates "Maximum" Lethality**
- **LED: High Velocity Selectively Aimed**

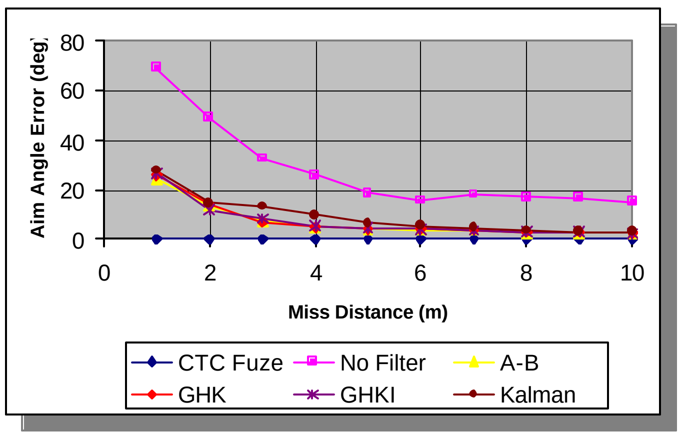


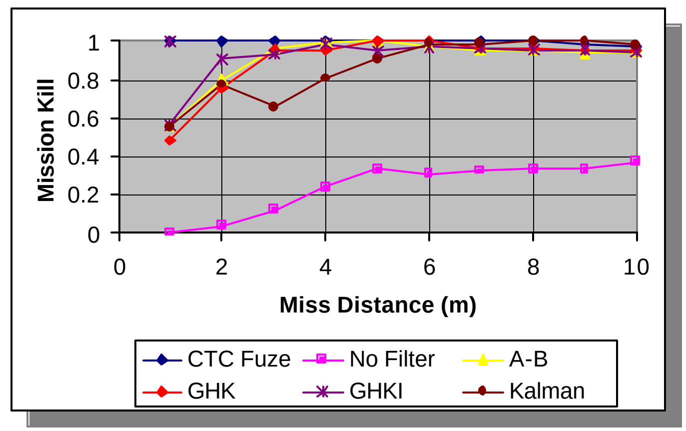


Avg. Closing Velocity: 1000 m/s

TBM Engagements

- **Slightly Higher Average Angle Errors Coupled with a Smaller Threat Size Produce a Notable Drop in PK at Low Miss Distances**



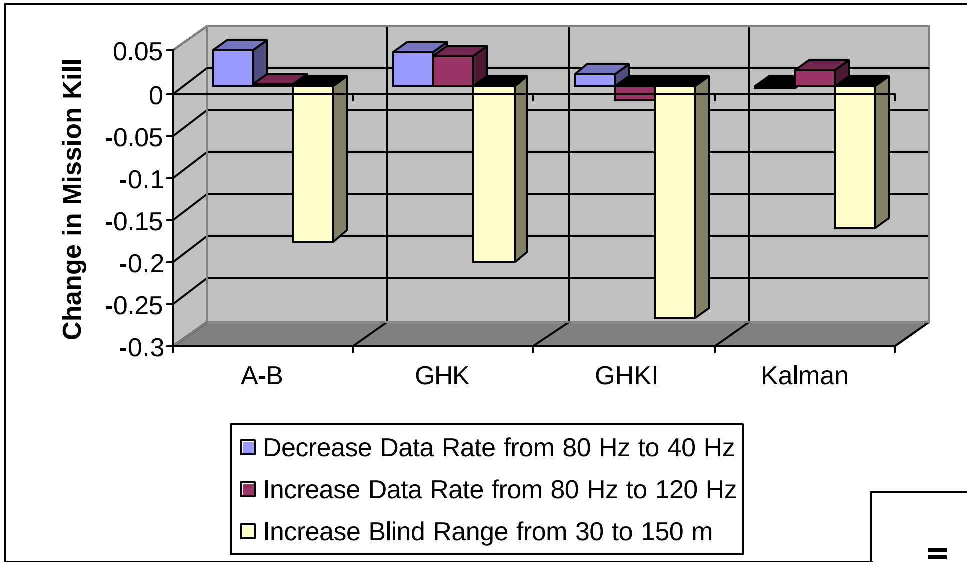


Error Conditions (Both Threats):

- ***+ / - 10 mrad Uniform, Unbiased Angle Noise***
- ***+ / - 1 m Uniform, Unbiased LOS Range Noise***

Avg. Closing Velocity: 2600 m/s

Sensitivity to Threat / Engagement Characteristics

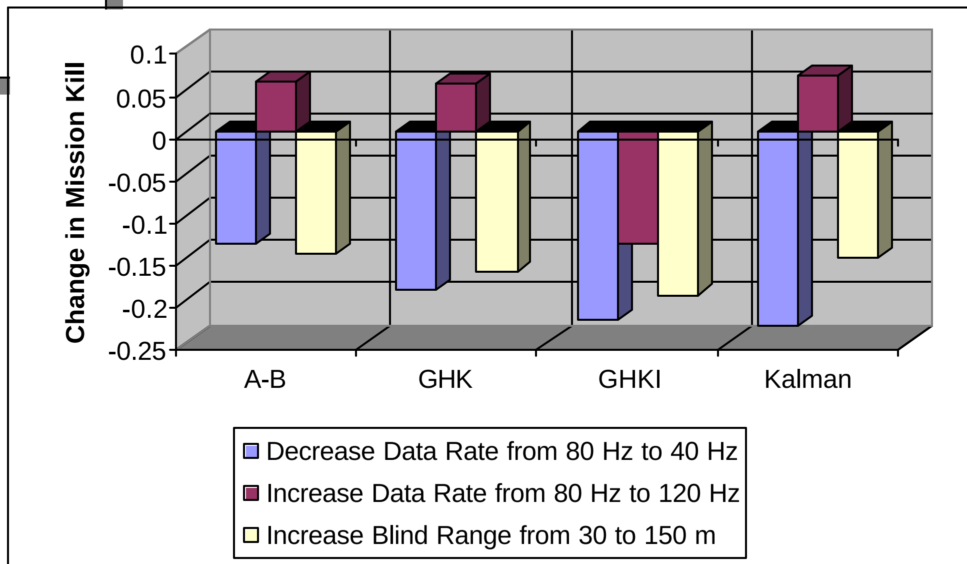


- **Changing the Sensor Data Rate Has Little Effect on GIF Performance During Cruise Missile Engagements, as Expressed in Terms of Lethality**
- **Increasing the Blind Range for these Relatively Slow Intercepts Degrades Lethality. Aim Angle Predictions are Most Affected.**

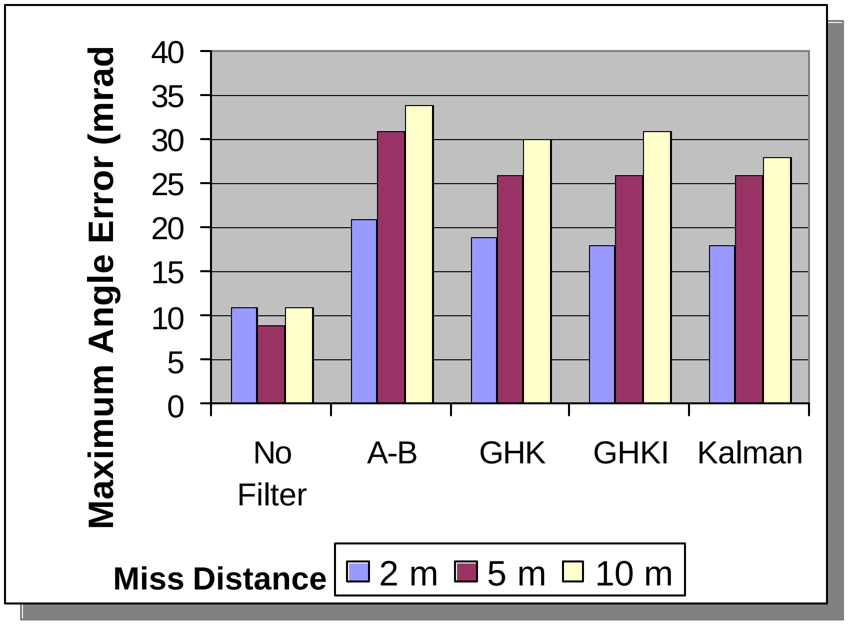
Cruise Missile Engagements

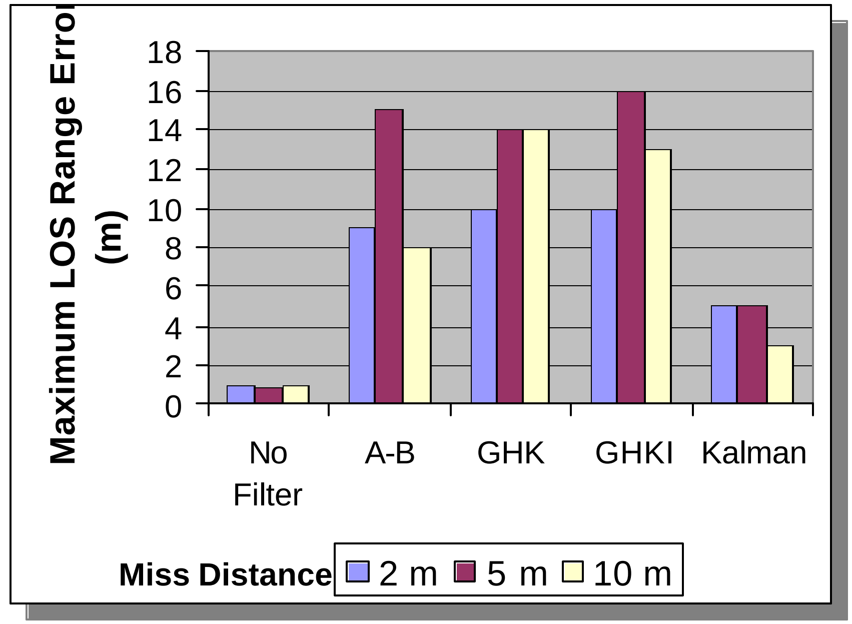
- **Decreasing Data Rate Negatively Impacts Performance During TBM Engagements, but Increasing Beyond 80 Hz Does Not Improve Results**
  - **Increasing Blind Range Reduces Lethality Performance. Fuze Time (Range) Predictions are Most Affected.**

TBM Engagements



Maximum Sensor Errors
Cruise Missile Engagements





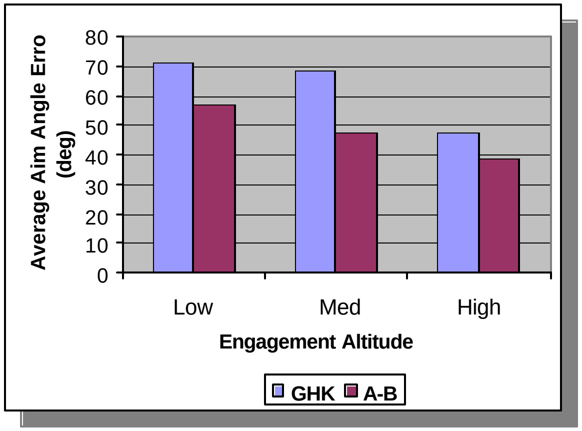
- Error Sources are Uniform about a Non-Biased Mean.
- These Values are Not "Deterministic" But Rather Provide a Comparison Between the Candidate Digital Filtering - State Estimation Techniques.
- The Simple Two-State Alpha-Beta Filter Performed Well In Most Cases.
- The Kalman Filter Consistently Performed Poorly, Compared to the Others, Given LOS Range Errors.
- Results were Similar for TBM Engagements.

Modification of Baseline GIF

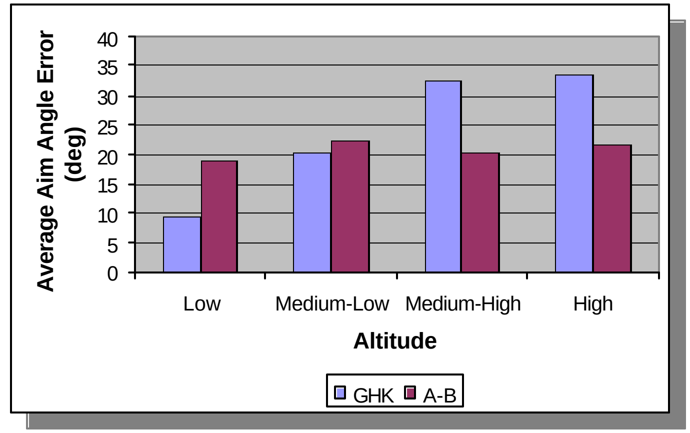
Alpha-Beta Filters were Installed to Replace the 3-Matched GHK Filters.

Results Were Promising.

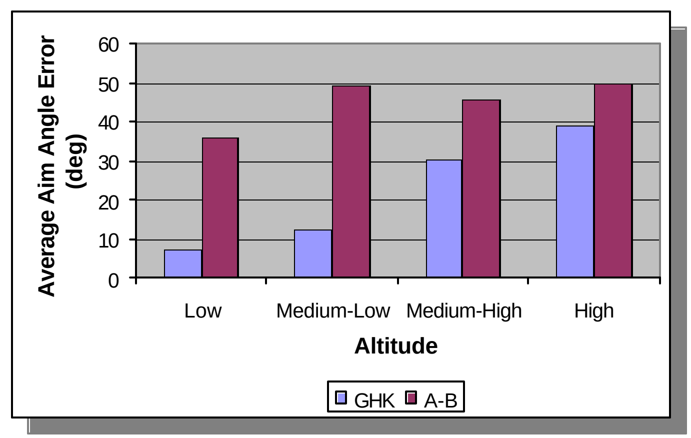
Cruise Missile Engagements



"Slow" TBM Engagements



"Fast" TBM Engagements



- **The High Angle Noise Values Encountered in Cruise Missile and Slow TBM Engagements Contributed to the Better Performance by the Alpha-Beta.**
- **Low Angle Noise was Encountered in the Fast TBM Engagements - Illustrating the Advantage of a 3-State Filter In the Quiet Environment.**

Conclusions

- **A Two-State Filter May Perform Better than a Three or More State Filter in a Noisy Environment:**
  - **Derived Accelerations Can Overwhelm Actual Target and Missile Accelerations, Most Notably at High Sensor Data Rates.**
  - **In This Study, the Third and Fourth State Coefficients Were Set Extremely Low to Compensate for Derived Accelerations.**
- **Miss Distance Heavily Influences GIF Aim Angle Prediction Accuracy:**
  - **Directional Aiming is Not Possible Whenever the Miss Distance is Equal to or Less than the Sensor Errors.**
  - **Systems with Very Small Miss Distances May not be Good Candidates for any LED Requiring Pattern Aiming.**
- **Increasing System Data Rate Can Improve GIF Predictions, but with Diminishing Returns. Increasing Data Rate Can Reduce Three State (and Higher) Filter Performance due to Derived Accelerations.**
- **Minimizing Blind Range is Important in All GIF Applications.**

KDI Precision Products, Inc.
An ISO 9001 Registered Company

IMPROVED ARTILLERY PROXIMITY FUZE

Presented By:

Bob Hertlein, Dave Lawson

KDI Precision Products, Inc.

Telly Manolatos

Electronics Development Corp

Presentation Outline

- Need for Improved Artillery Proximity Fuze
- Design Goals
- Design Approach
  - RF front end
  - Signal processor
  - Battery
  - S&A
- Future design enhancements

Need for Improved Artillery Proximity Fuze

- MK417/418 has history of problems
  - Early bursts
  - Duds
  - Poor HOB control
  - Not production-friendly
  - Obsolete parts
- No low-cost alternatives capable of both air and ground targets

Design Goals

- Capable of air and ground targets
- Operation independent of round (not body-excited)
- NATO shape factor
- Surface mount technology
- Low cost
- Impact back-up mode

Design Approach

- RF front end
- DDR signal processor
- MK41 S&A
- German Battery

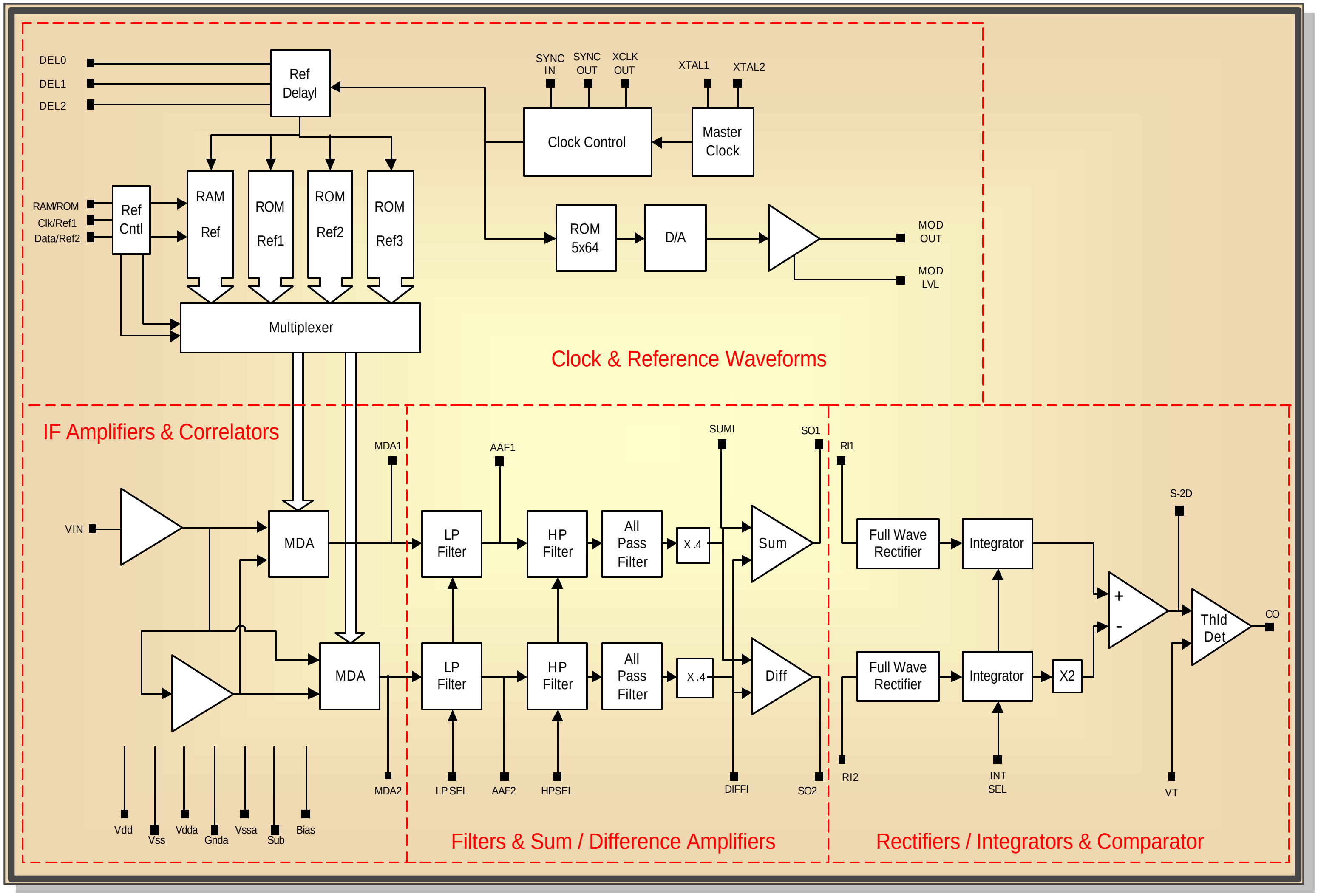
RF Front End

- Optimized for air targets
  - Low noise discrete oscillator
  - Monopole antenna for good side coverage
- Will work well with ground targets
  - Low-angle approaches benefit from side coverage
  - enhanced sensitivity overcomes front-end null in high-angle approaches

DDR Overview

- Based on FM-CW architecture
- Correlation waveforms stored in memory
- Accurate HOB independent of target reflectivity
- Highly resistant to ECM
- Completely integrated for reliability, low cost
- DDR currently fielded in the highly successful M734A1 Multi-option Fuze for Mortars

Block Diagram of KDI ASIC



Summary of Key ASIC Features

- Programmable reference waveforms
  - Allows tailoring of target-specific range responses
  - Downloaded from µP (can be changed during flight)
- Low noise for use in air target applications
- Low Power
- Selectable wide band filters
  - Can process wide range of Doppler frequencies
- Multiple ASICS can be synchronized
  - Allows implementation of more complex fuzing algorithms

S&A

- MK41 is a qualified design
- Low cost
- Performance parameters:
  - Setback g level: 26,000 g
  - Spin rate: 410 rps
  - Velocity: 3075 ft/sec

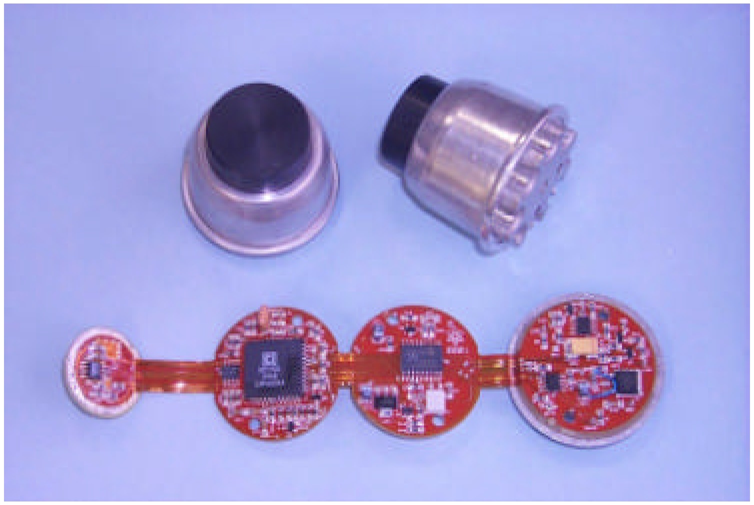
Battery

- German made (Friemann & Wolf)
- Chemistry: Pb/HBF4/PbO2
- Proven design for artillery
- Performance parameters:
  - Operational life: 150 seconds
  - Current: 150 mA max
  - End of life voltage: 5.5 Volts min
  - Rise time: 100 mSec max
  - Required setback: 1200 g's min
  - Required spin: 2500 rpm min
  - Operating temperature: -45F to +145F

Photos of Old Vs. New Design

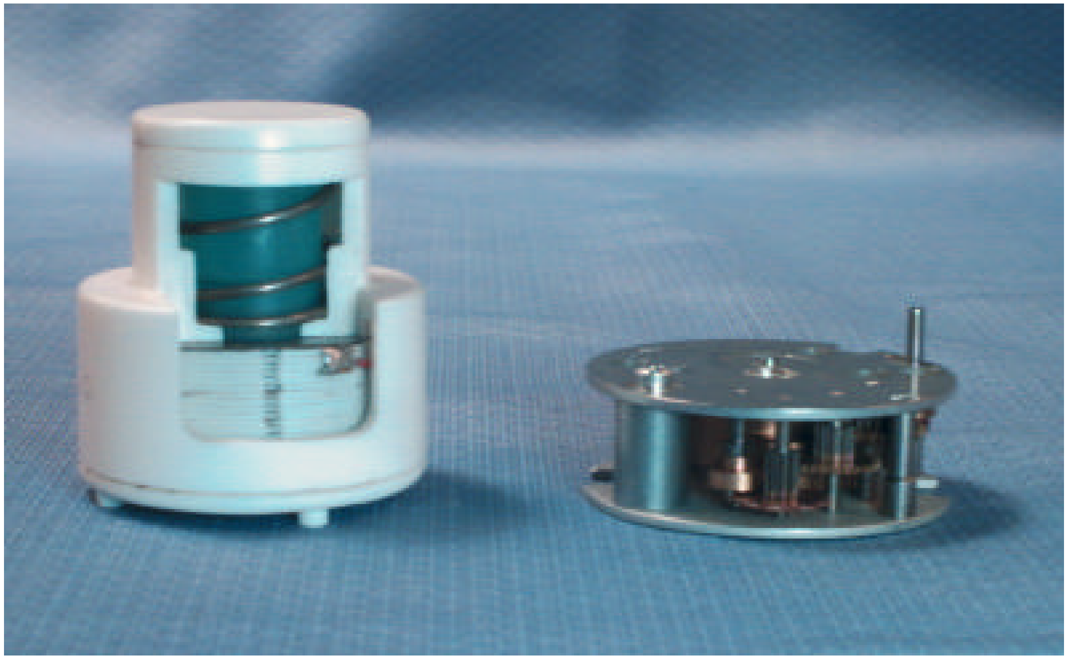
EDC

New Design:

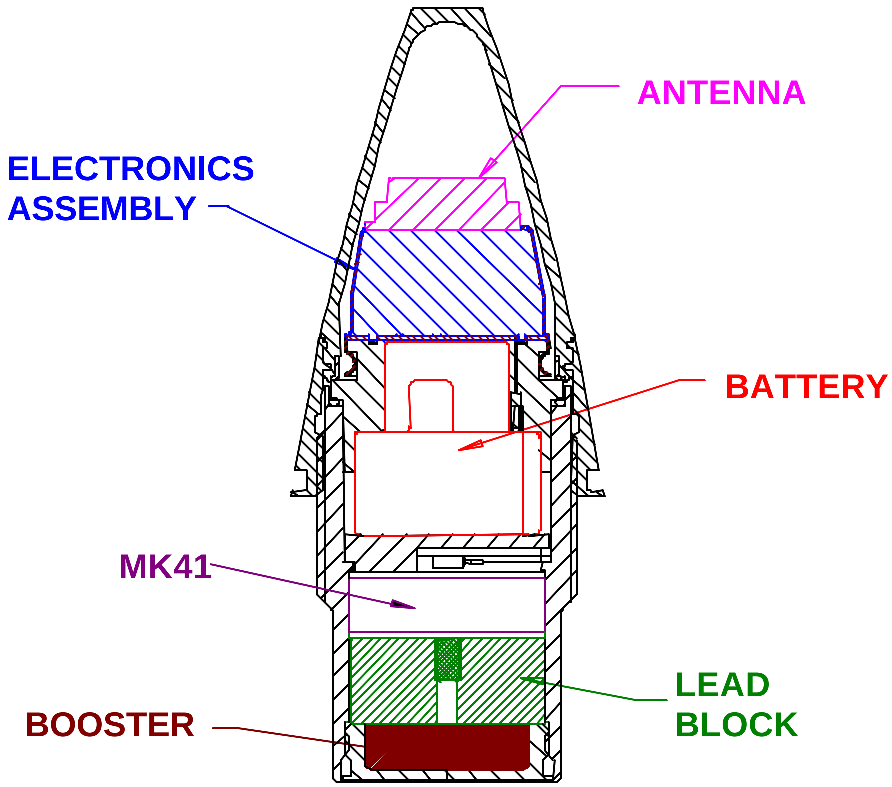


Old Design:

Photo of Battery and S&A



Computer Plot of Cutaway



Future Design Enhancements

- ASIC flexibility provides adaptability to a wide variety of systems
- Possible enhancements include inductive-set programmable time capabilities

Joint Advanced Missile Instrumentation (JAMI) System Flight Termination Safe and Arm

Presented

By

Bruce Hornberger

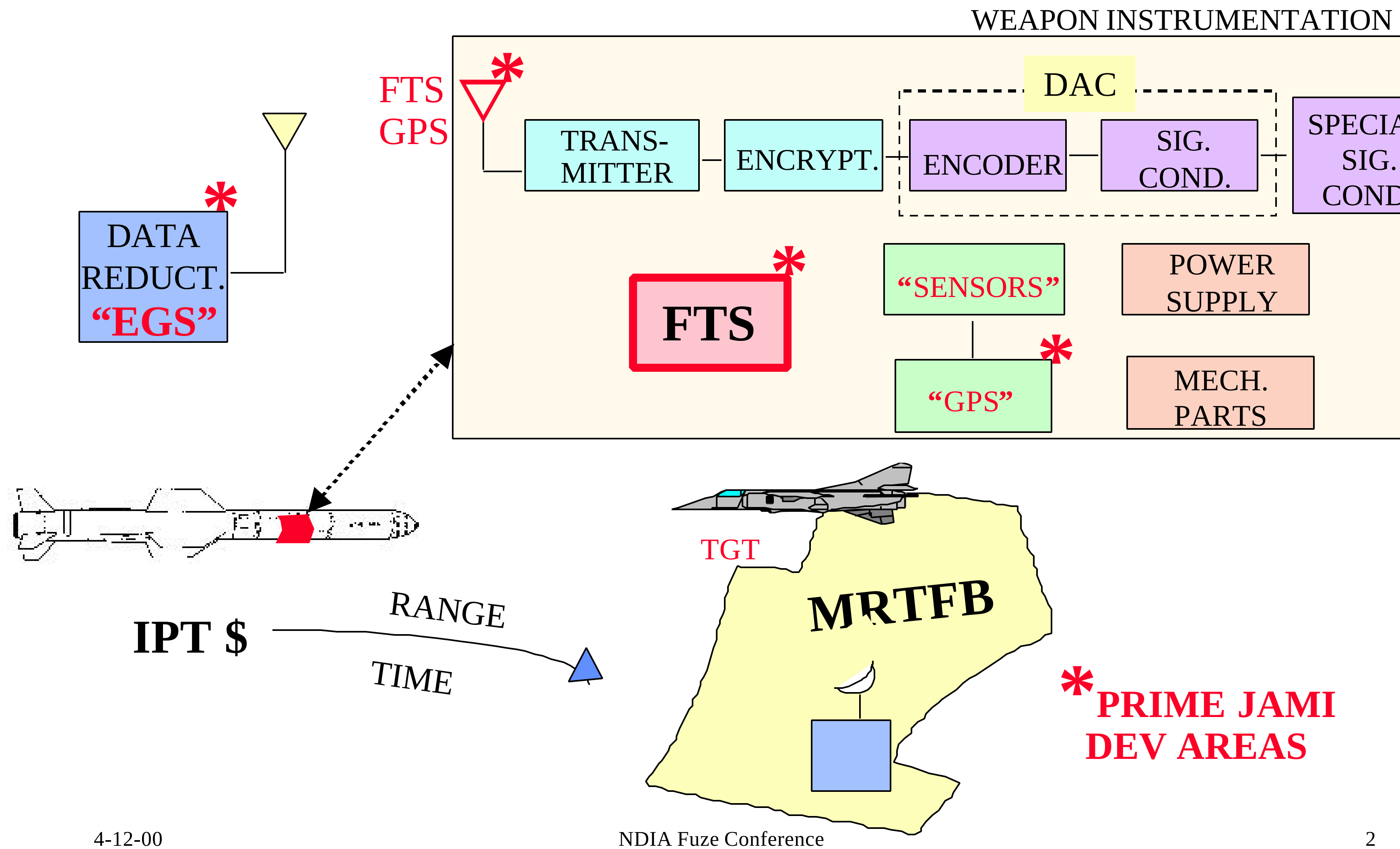
NAWC/WD China Lake

Code 478300D

760-939-7674

hornbergerba@navair.navy.mil

JAMI System


WEAPON INSTRUMENTATION
FTS
GPS
*
TRANS-
MITTER
ENCRYPT.
DAC
ENCODER
SIG.
COND.
SPECIAL
SIG.
COND.
*
FTS
"SENSORS"
POWER
SUPPLY
*
"GPS"
MECH.
PARTS
*
DATA
REDUCT.
"EGS"
TGT
MRTFB
IPT $
RANGE
TIME
*PRIME JAMI
DEV AREAS

JAMI System

- JAMI Will Exploit GPS Technology to Allow World-wide Test & Training--Eliminating, in Most Cases, the Need for Range-specific (or Multi-system) Facilities.

- END GAME SCORING CAPABILITIES
  - $\pm$ 2 Feet Vector Position Accuracy
  - Velocity Measurement to 10,000 Ft/sec
  - 50 G Acceleration w/o Loosing GPS Track
  - Attitude Accuracy < 0.5 Degree
  - Timing Correlation $< 100\ \mu s$

FTSA Targeted Applications

- Bomb (e.g. JDAM)
- Glide (e.g. JSOW)
- Missile (e.g. STD MSL, HARM)
- Arm on Rail (e.g. STD MSL Targets)

JAMI TEAM

- Program Mgr: Mr. Don Scofield, NAWCWD, China Lake, CA

- Tri-Service component points of contact:

Army:	Mr. Robert Epps, RTTC, Redstone Arsenal, AL
Navy:	Mr. Dave Powell, NAWCWD, Pt Mugu, CA
Air Force:	Mrs. Carolyn Coleman, 46TW/TSWI, Eglin AFB, FL
Range Safety:	Mr. Jerry Mathre, NAWCWD, China Lake, CA
BMDO:	Ms. Debbie Giordano, BMDO, Wash DC

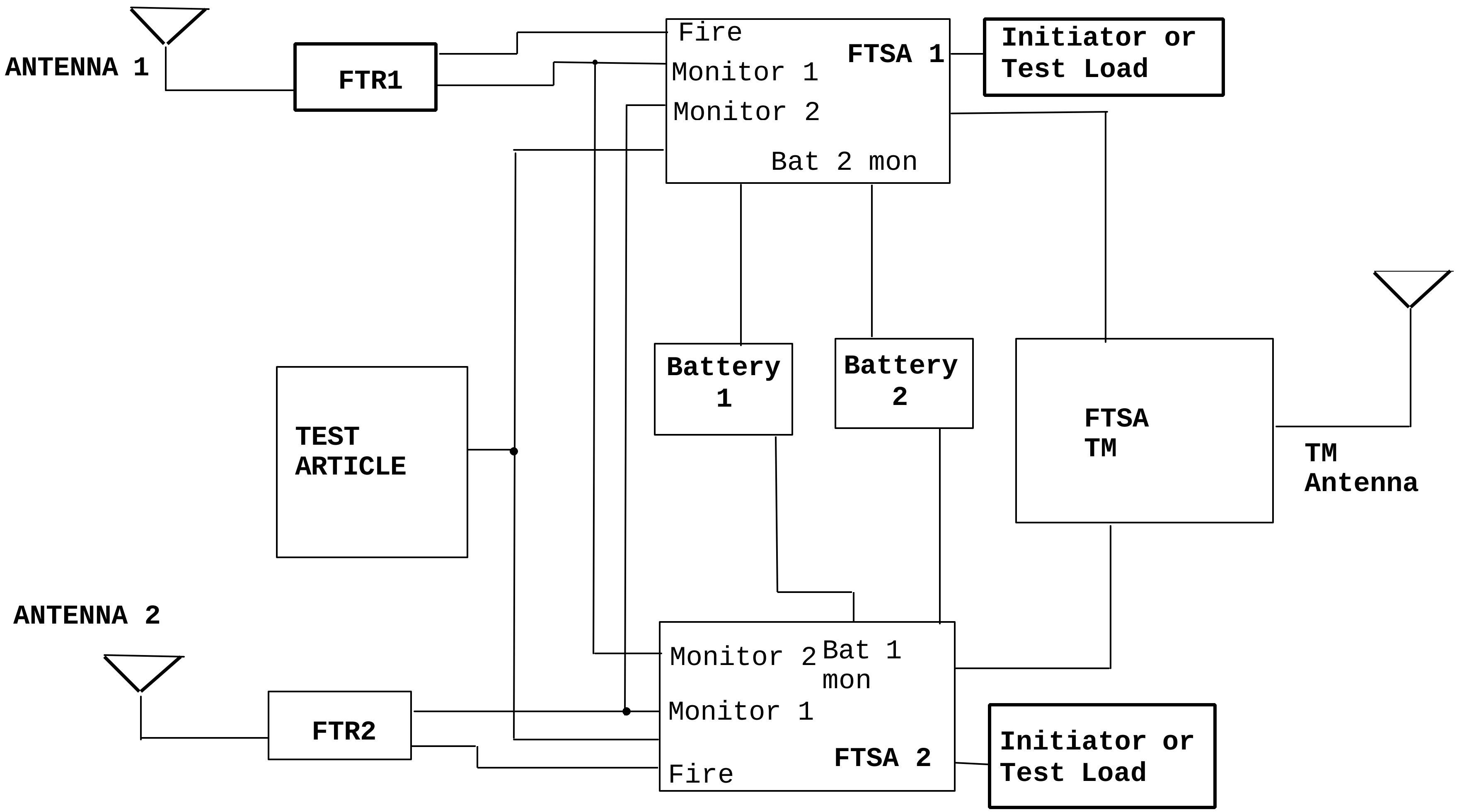
FTSA VS S&A

- FTSA
  - – Overriding Concern is to Not Allow the Weapon to Go Outside the Range Footprint
    - Failsafe: FTSA Initiates Termination
  - – Defining Specification is RCC 319-99
- S&A
  - – Overriding Concern is to Not Allow Unintended Initiations
    - Failsafe: S&A Duds
  - – Defining Specification is Mil-Std-1316

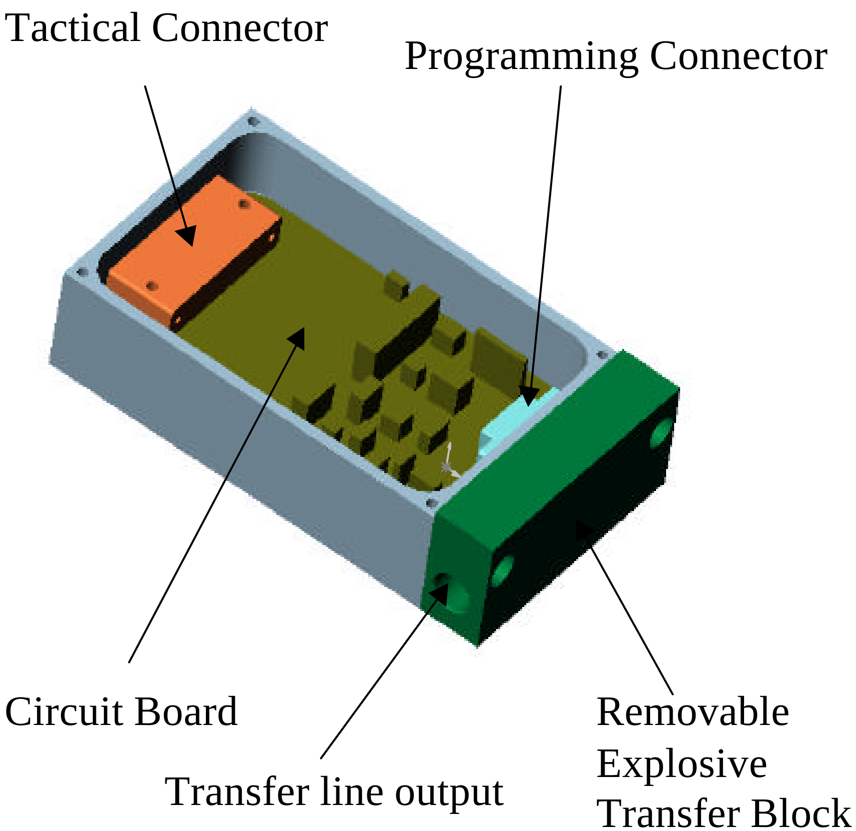
CONFLICTING OBJECTIVES

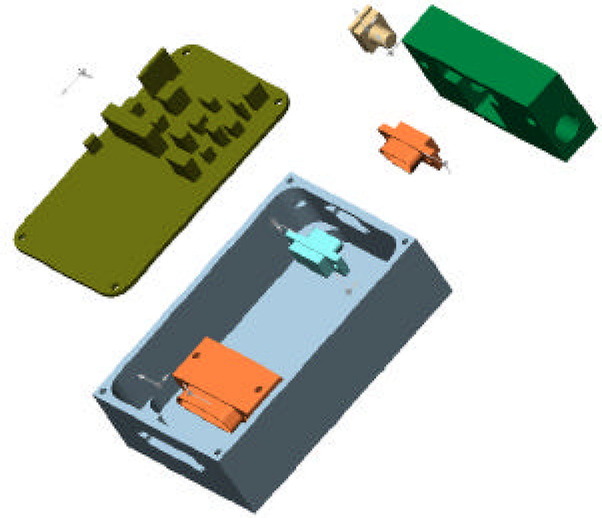
- FTSA & S/A Have Conflicting Objectives and Requirements
  - The JAMI FTSA Incorporates Features that Conflict with Traditional S/A Design Methodology
    - MIL-STD-1316 Is Not Invoked on the JAMI FTSA
    - Fail Safe Features Differ
    - Safety Environments Programmable

JAMI FTSA


ANTENNA 1
FTR1
Fire
Monitor 1
Monitor 2
Bat 2 mon
FTSA 1
Initiator or Test Load
Battery 1
Battery 2
FTSA TM
TM Antenna
TEST ARTICLE
ANTENNA 2
FTR2
Monitor 2
Bat 1 mon
Monitor 1
Fire
FTSA 2
Initiator or Test Load

JAMI FTSA





- **Features:**
  - Programmable Performance
  - Low Cost
  - Small size (8 cubic inches)

JAMI FTSA Requirements

- Compliant With RCC 319-99
- Programmable (at test facility) For Multiple Applications
- Small Size (< 8 in^3/unit)
- Low Cost (< $2200/unit)
- Qualified To “Worst Case” Environmental Levels
  - Based on Environments of Potential Users
- Removable Explosives (EFI, Etc.)
- Fully Testable (Including HV Output)

PROGRAMMABLE INPUTS

- Failsafe Enable (Fire)
  - Loss of Monitor (tone)
  - Loss of Power
- First Motion Enable
  - First motion Valid Time
- Acceleration Enable
  - Axis of Acceleration
  - Acceleration Level
- Umbilical Disconnect
- Safe Separation Time

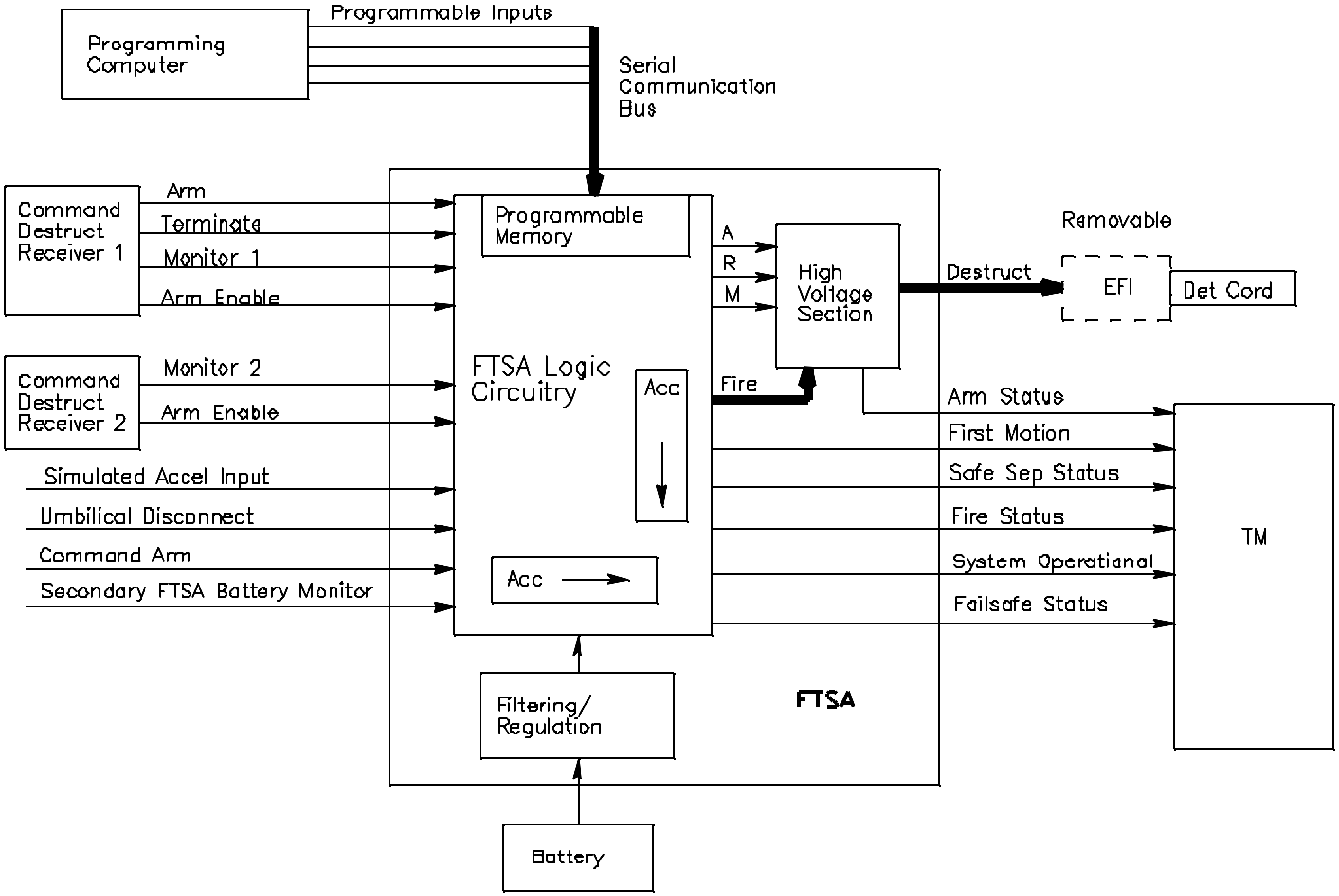
NON PROGRAMMABLE INPUTS

- Terminate Command
- Simulated Accelerometer Input
- Battery Power
- Arm Enable

OUTPUTS

- Flight Destruct (Explosive)
- Safe/Arm Status
- Fire Status
- Safe Separation Status
- First Motion Status
- System Operational
- Failsafe Status

FTSA INTERFACE



JAMI FTSA FIRESET

- Novel Trigger Design (Patent in Process)
- Small In Size
- Low In Cost (<$20)
- High Reliability
  - 3200 shots @ 1500A
- No Unique Parts
  - All COTS

TEST ENVIRONMENTS

- Range Safety Document RCC 319-99
  - May be First FTSA Fully Qualified to New Document
- Database of Environmental Profiles of Numerous Weapons Systems

DEVELOPMENT UNDER CRADA

- Cooperative Research and Development Agreement
  - Raymond Engineering Operations (REO)
  - Signed 12 April 1999
- Division of Responsibilities
  - China Lake (POC Andy Yuenger 760-939-7768)
    - Electrical/Explosive Design and Development
    - Environmental Testing
  - REO (POC Dale Spencer 860-632-4477)
    - Packaging
    - Hardware Manufacturing

STATUS

- Spec Nearing Completion
- Electrical Design Nearing Completion
  - Breadboards Being Debugged
- Electrical Volume Study Complete
- Fireset Studies Complete
- Qual Plan in Process
- Expect Qualification Completion Nov 2002

JAMI FTSA BENEFITS

- Low Unit Cost
- Small Volume
- No need for Application Specific Redesign
- Minimal Application Specific Implementation Costs
- Ranges Could Retain a Stockpile Reducing Schedule Impacts

Pumice Technology

NDIA Munitions Symposium VII
April 10-12, 2000

John Kandell

IMTTP Pumice Program Engineer

Naval Air Warfare Center Weapons Division

China Lake, California 93555-6100

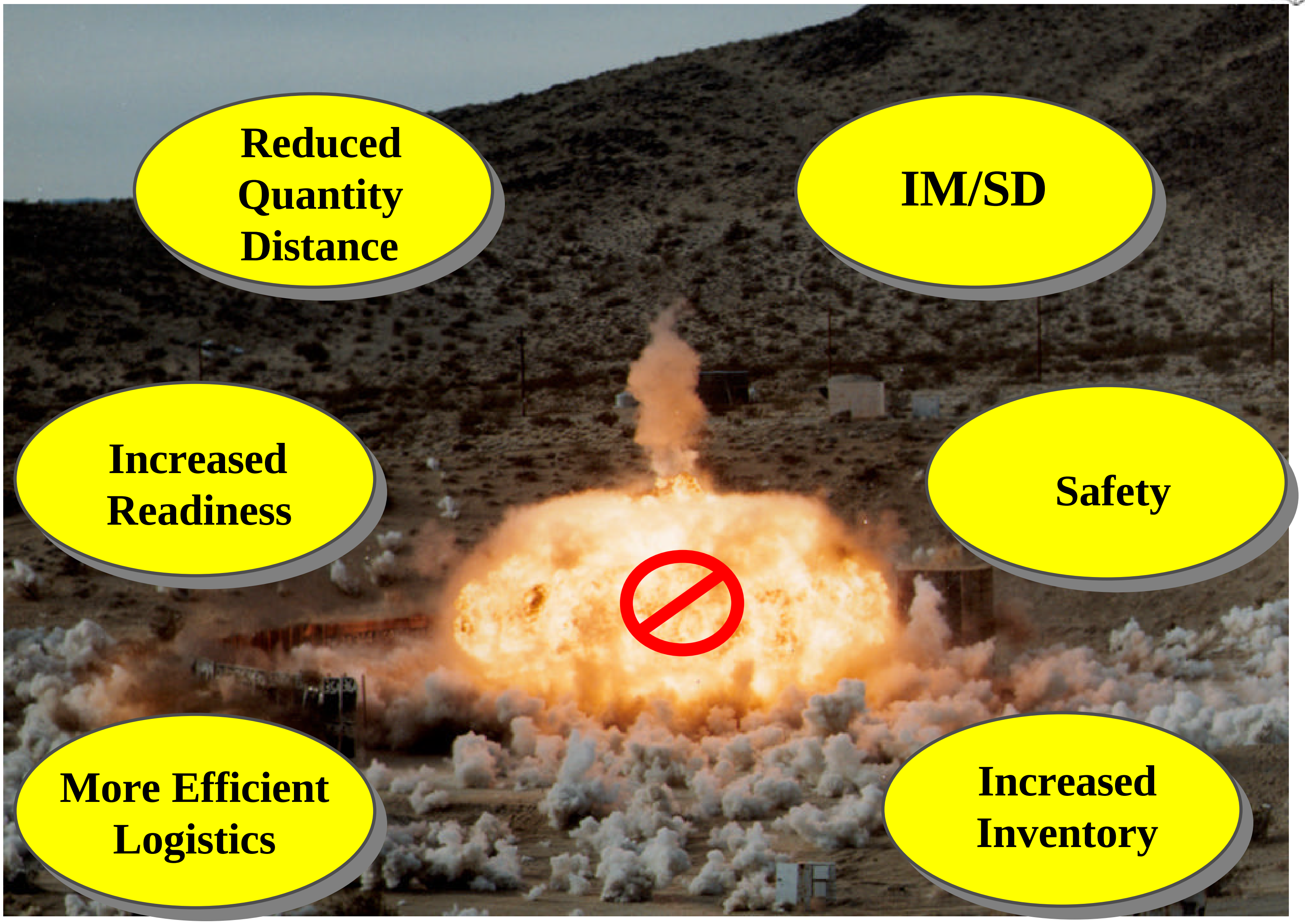
phone: (760) 939-7658; fax: (760) 939-7190

DSN 437-7658

Email: kandelljk@navair.navy.mil

Approved for public release; distribution is unlimited.

Benefits of Pumice



Overview

- Pumice Technology addresses the issue of Sympathetic Detonation
- Requirement:
  - Insensitive Munitions (IM) sympathetic detonation requirement for weapon systems
    - NAVSEAINST 8010.5B paragraph 7 states that Navy weapon systems must satisfy the requirements of MIL-STD-2105A, which includes sympathetic detonation
- Funding provided by the Navy Insensitive Munitions Technology Transition Program (IMTTP)

<u>Sympathetic detonation is a Navy Insensitive Munitions requirement</u>

Navy Weapons

- Sympathetic detonation (SD) non-compliant Navy Weapons programs
  - Bombs
    - JDAM, GBU-24B/B, Mk-80s, BLU-100/111A/B, BLU-117
  - Rockets
    - MK 66 Mod 2, Mk 67 Mod 1, WDU-4A/A, M151, M257, M278, LAAW, Mk 352 Mod 2, M427 ...
  - Missiles
    - Javelin, TOW, JSOW, Hellfire, Sparrow, Tomahawk, RAM, HARM, Predator...
  - Ammunition
    - 40mm, 20mm, 25mm, MAAWS …

<u>A number of Navy weapons are not SD compliant</u>

Solution

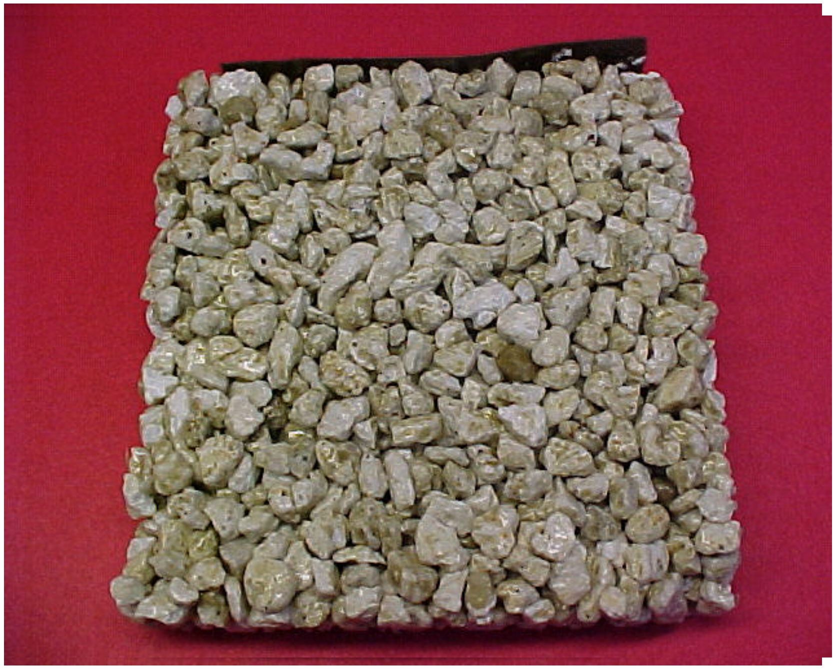
- The volcanic ash, commonly called pumice, has the unique capability of absorbing a large amount of explosive shock energy
  - Fracturing of individual pumice pebbles absorbs energy from an explosive shock
- Pumice is:
  - affordable ($17.50/cubic yard)
  - commercially and readily available
  - light weight
  - easily incorporated into various configurations

Pumice can solve the sympathetic detonation problem

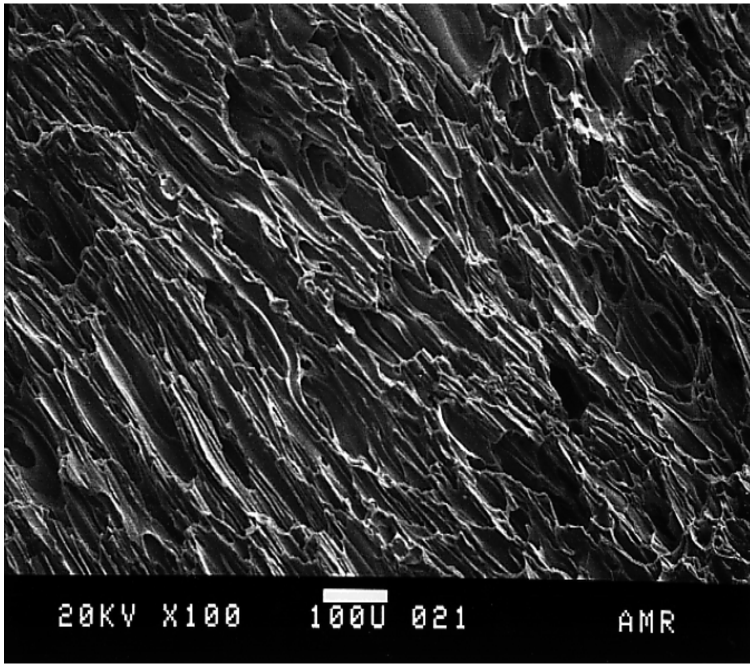
Rigid Pumice Configuration

- 3/8-inch spheroidal pumice pebbles held together by epoxy
- Composition: 63-67% SiO_2 (Silicon Dioxide, Silica) and 17-19% Al_2O_3 (Aluminum Oxide)

STANDARD PUMICE AND EPOXY CONFIGURATION



100X MAGNIFICATION OF A PUMICE PEBBLE



Current Use of Pumice

- AGM-84H SLAM ER guided missile uses pumice in the shipping/storage container (CNU-595/E)
  - Pumice allows the weapon to meet the sympathetic detonation requirement
  - Minimal program impact
    - 9.75% increase in container weight
    - 10% increase in cost of container
- Navy and Marine EOD teams have incorporated pumice into containers stored in explosive magazines
  - Quantity Distance (QD) arc reduced to zero
  - Pumice containers allow more explosive to be stored in a single magazine

Pumice is in the fleet

IMTTP Program Objective

- Incorporate pumice technology into existing and future weapon systems in transportation/storage and utilization configurations to meet the sympathetic detonation requirement
- Refine the pumice design tool/model
- Characterize and evaluate the performance of a flexible-foam-pumice material
  - Material can be used as a replacement for existing shipping container foam to mitigate explosive shock as well as transportation and handling shock
- Validate other commercial sources of pumice

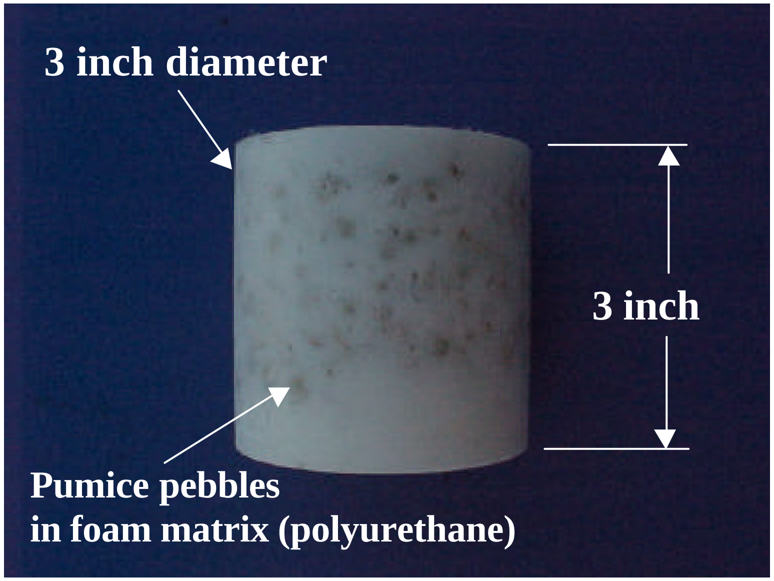
Increase use of pumice in Fleet to enhance safety

Pumice Tests Overview

- Flexible-foam pumice
  - Pumice evaluation test setup
  - Flexible-foam pumice test results and model
  - Planned testing
- Pumice sub-scale container test and model
- SLAM ER Tandem Warhead sympathetic detonation test and model

Flexible Foam Pumice

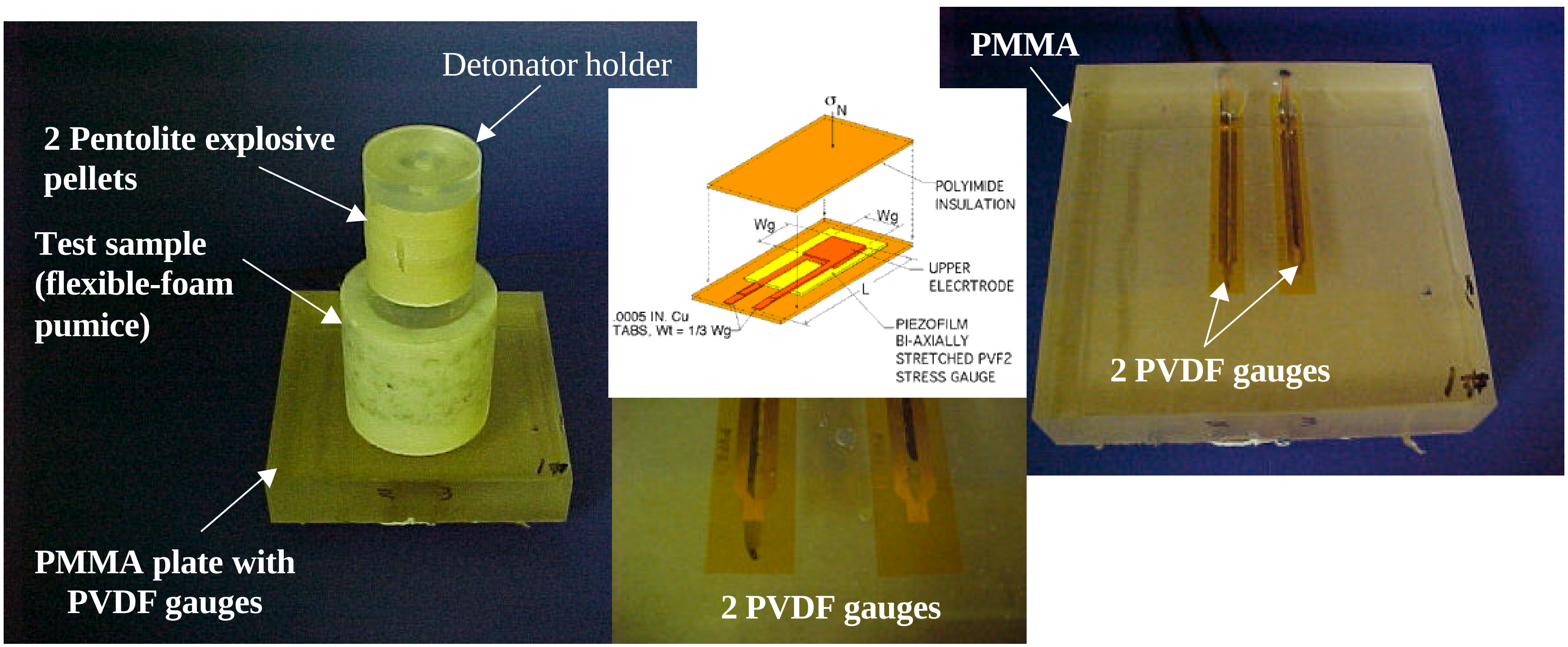
- Objective
  - Develop pumice foam with good shock attenuation
  - Add more flexibility to the use of pumice
    - Replace existing shipping container foam with flexible foam pumice
      - Provide transportation vibration and shock protection in addition to sympathetic detonation



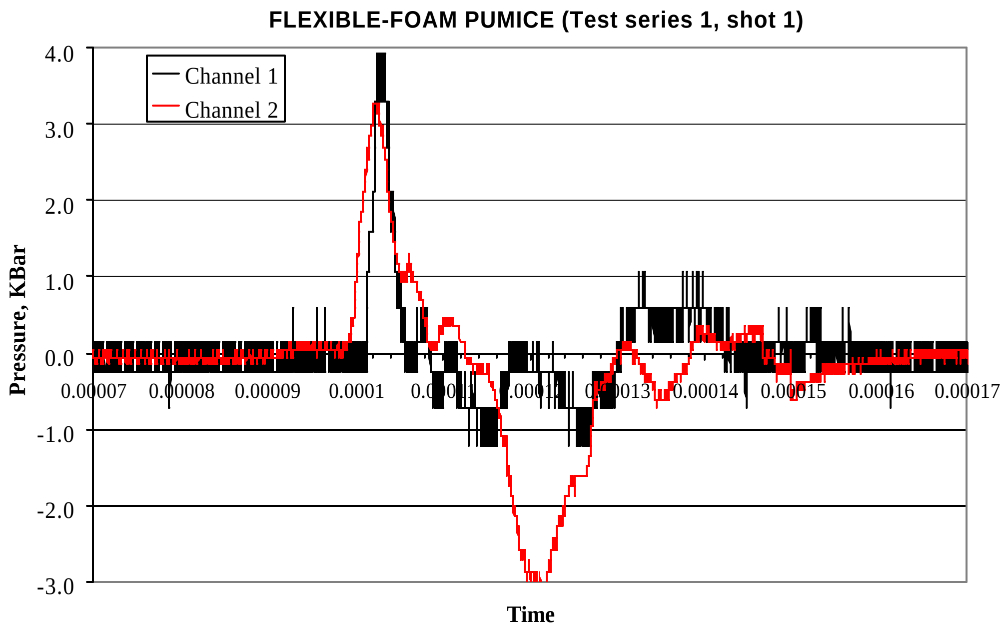
Pumice Evaluation Test Setup

PUMICE

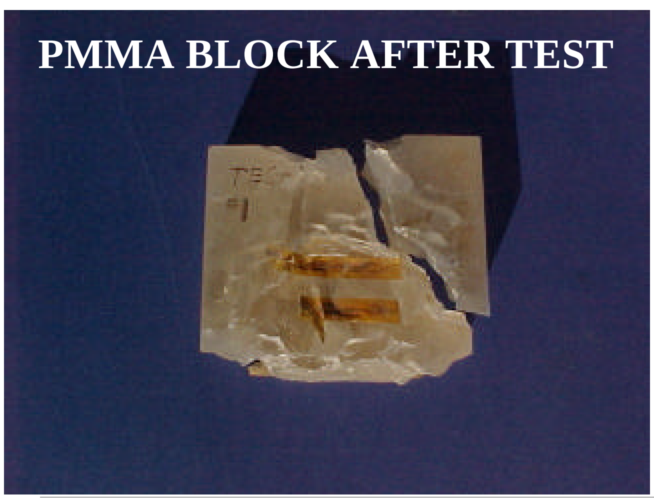
- Similar to standard Naval Ordnance Laboratory (NOL) Large Scale Gap Test (LSGT)
  - Pumice sample under evaluation is used as opposed to explosive
  - PVDF gauges replace steel witness plate
    - Gauges give pressure versus time, provide more information

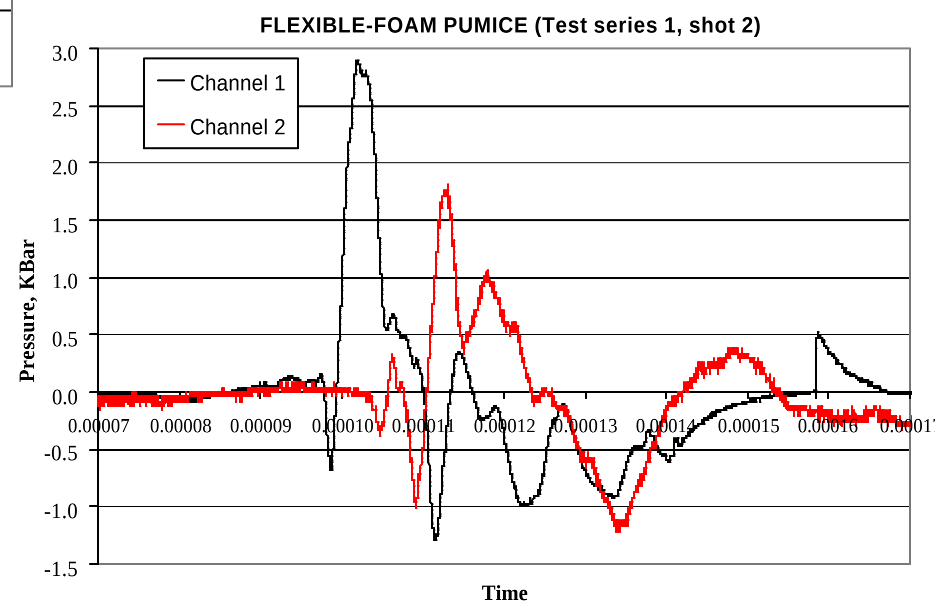


Pumice Evaluation Test Results



- Shock input of 80 kilo-bar
- Measured maximum shock of 4.0 kbar
  - 95% reduction in pressure
  - Plan on evaluating total energy
- Need to validate gauge output



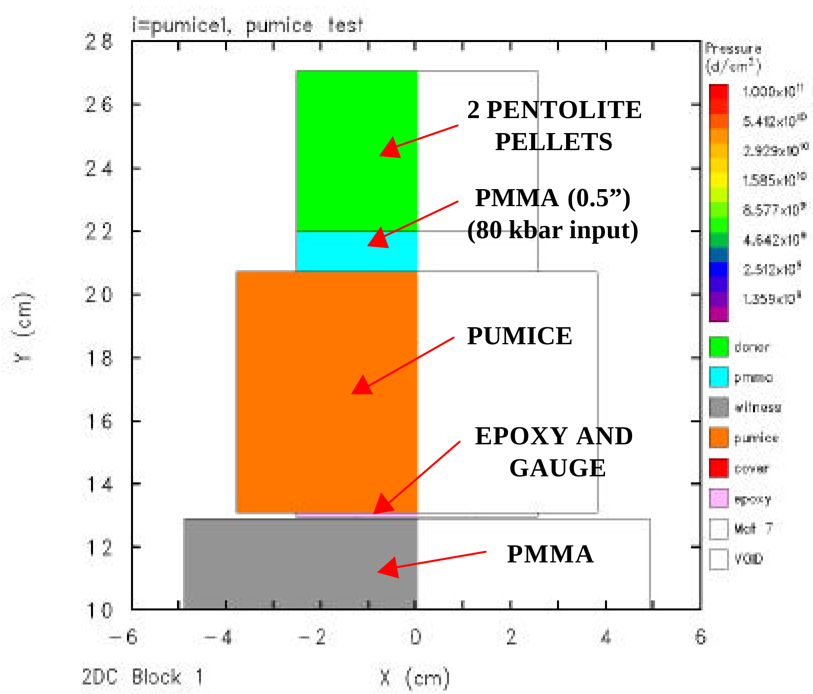


Pumice Evaluation Model

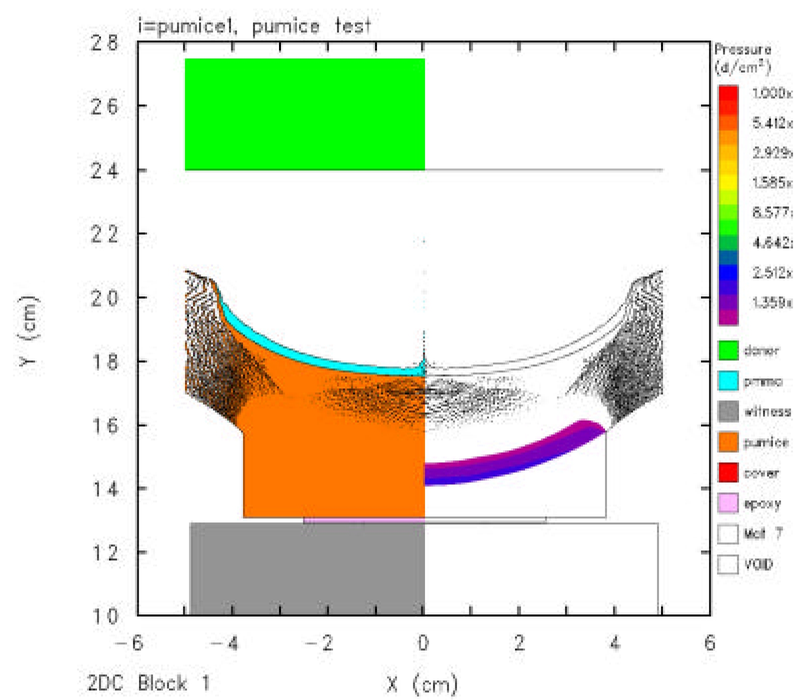
PUMICE

- Hydrocode CTH from Sandia National Laboratory used to predict performance of pumice
  - Porosity (p-alpha) model used for the pumice

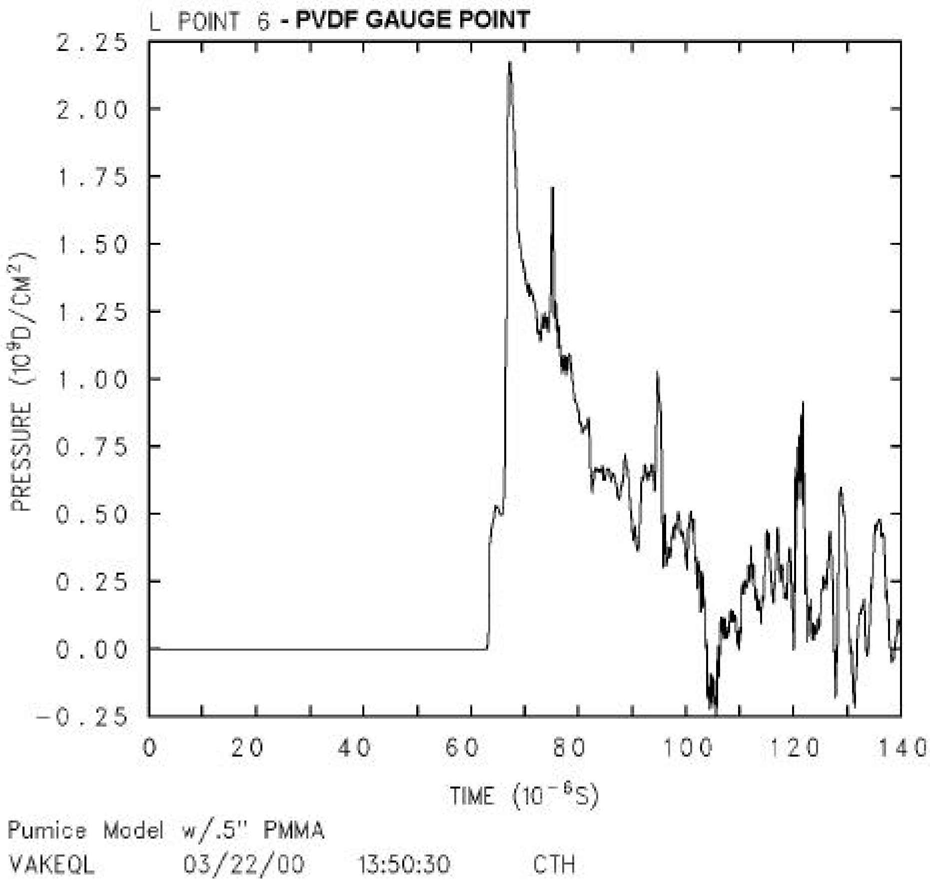
CTH MODEL GEOMETRY
(time=0)



CTH MODEL RESULTS
(time=50μs)



Pumice Evaluation Model



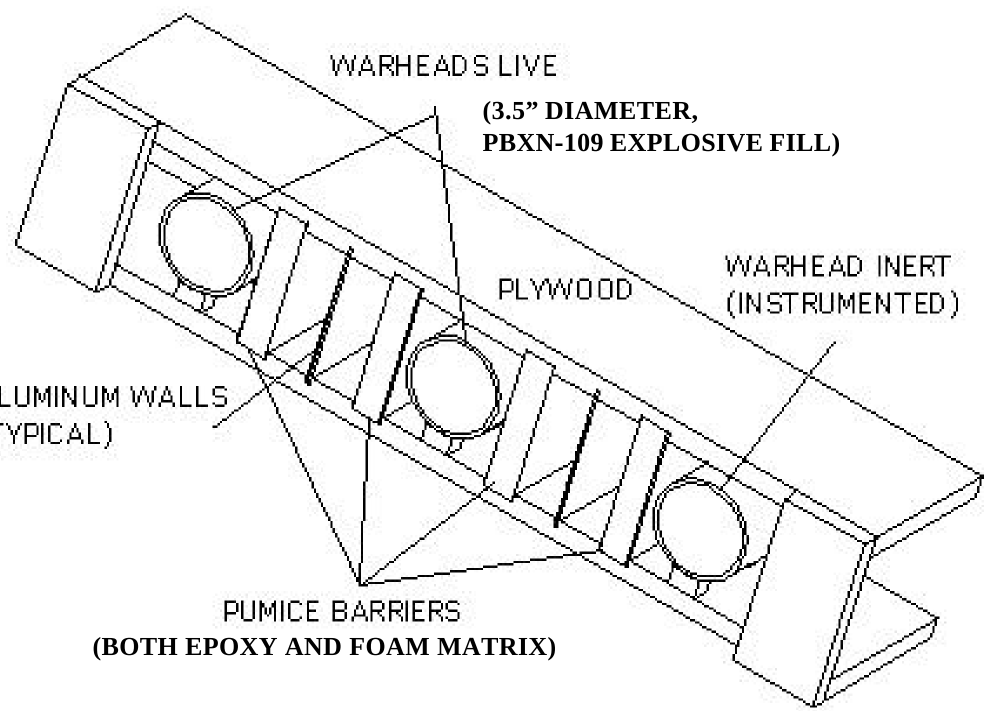
<u>CTH MODEL PRESSURE Vs. TIME</u>

<u>Model Prediction vs. Test Results</u>

- CTH Hydrocode model
  - Peak pressure of 2.125 kbar
  - Pulse duration of 40 μs
- Test results
  - Peak pressure between 1.66 kbar and 3.92 kbar, 2.71 average
  - Pulse duration of 10 μs
- Action
  - Determine cause of variability in PVDF gauge readings
    - Noise in test setup
  - Conduct calibration test shots
  - Run CTH model with finer mesh density

Pumice Sub-scale Container Test

- Test conducted on sub-scale container to evaluate effectiveness of pumice
  - Full scale containerized weapon failed sympathetic detonation
  - No reaction from the acceptor warhead



Pumice Sub-scale Container Test

PUMICE

High speed photography of sub-scale container test

- Test conducted using rigid foam with maximum amount of pumice
  - No reaction from acceptor
  - Crushing and spall of pumice can be seen

Pumice Sub-scale Container Test

PUMICE

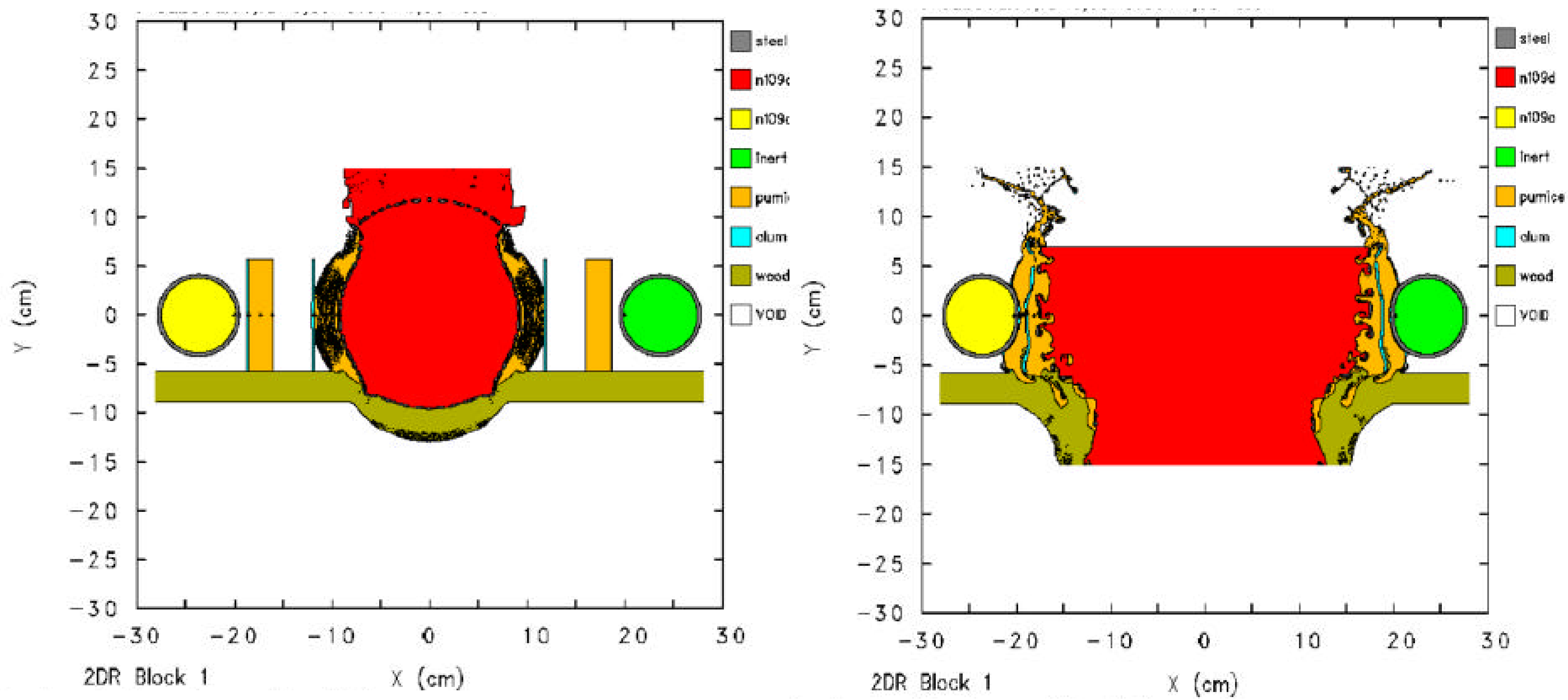
High speed photography of sub-scale weapon container test

- Test conducted using pumice in epoxy matrix
  - No reaction from acceptor
  - Crushing and spall of pumice can be seen

Pumice Sub-scale Container Model

PUMICE

- Hydrocode CTH used to model sub-scale weapon container



UNCLASSIFIED

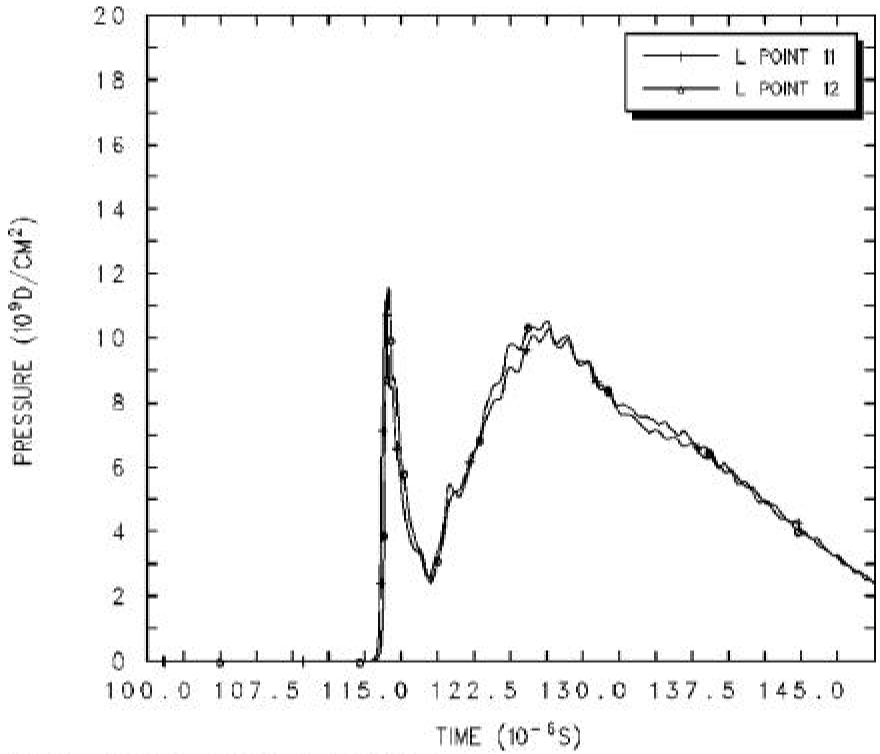
PATENT CAUTION

MAY CONTAIN PATENTABLE MATERIAL. TO BE RELEASED ONLY UPON SPECIFIC WRITTEN AUTHORIZATION FROM NAWCWD, CHINA LAKE, CA

Pumice Sub-scale Container Model

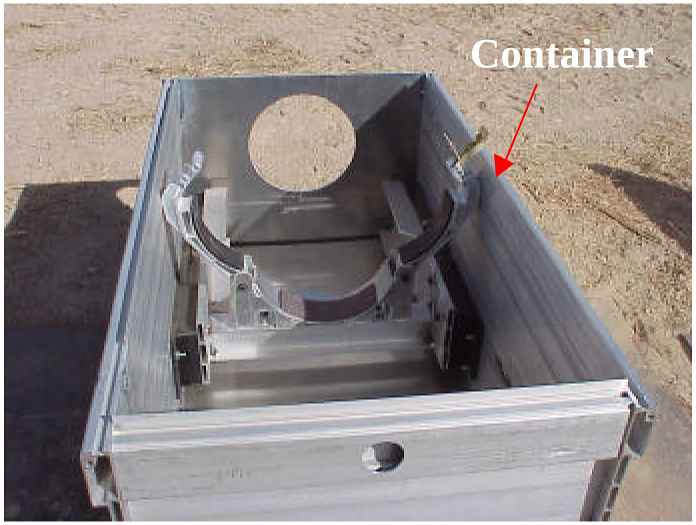
– Model predicted pressure of 10 kilo-bar compared to measured test pressure of 6 kilo-bar
  - No reaction predicted based on pressure level and duration
    – PVDF gauge used was different than evaluation tests

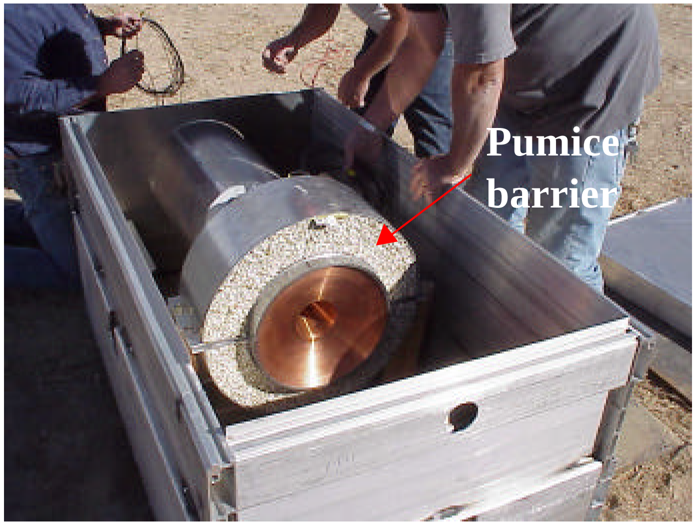
– Model predicted 80 kilo-bar without pumice and aluminum



<u>CTH model output to determine whether explosive will react</u>

SLAM ER Tandem Warhead SD Test

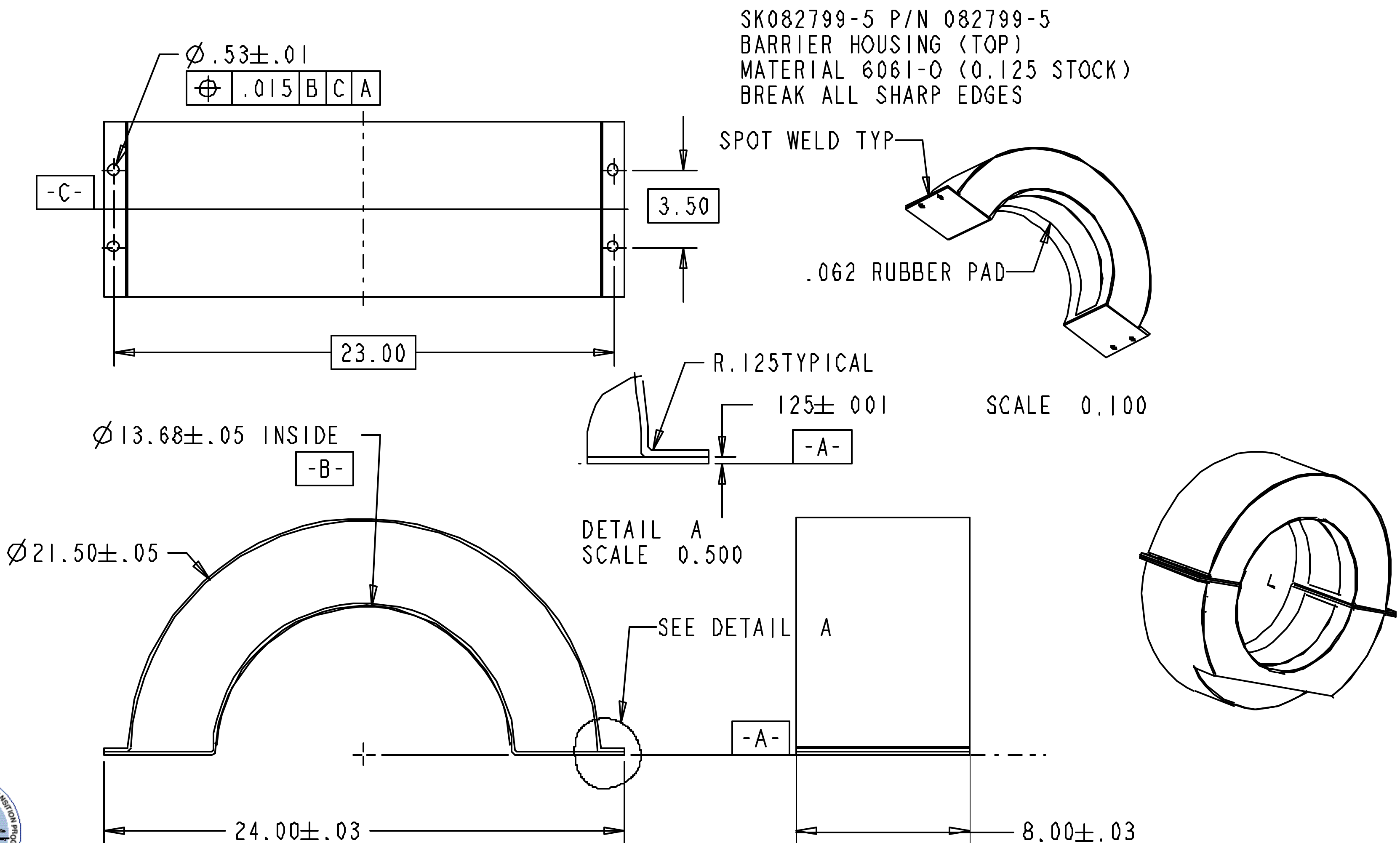




SLAM ER Tandem Warhead SD Test

- No reaction from warhead
  - WSESRB have not yet been briefed and provided ruling

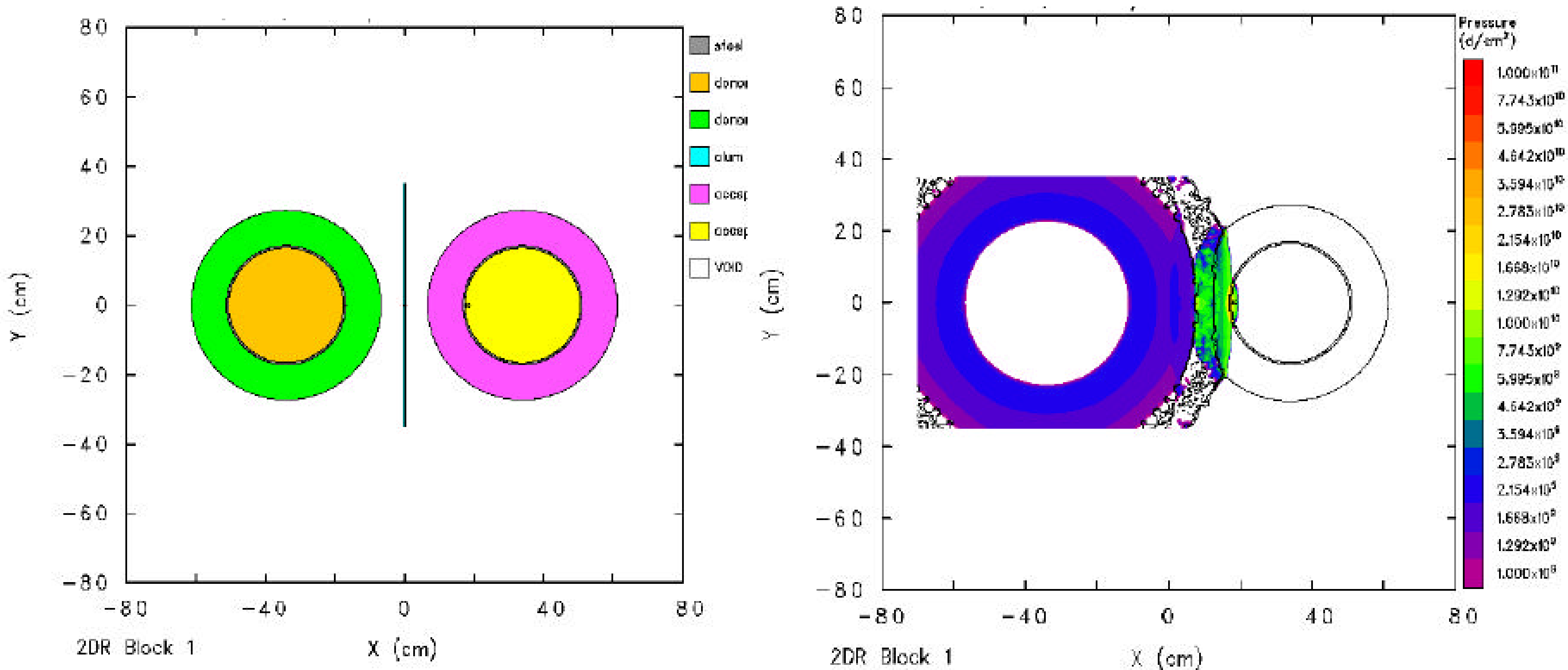
SLAM ER Tandem Warhead SD Test



SLAM ER Tandem Warhead SD Model

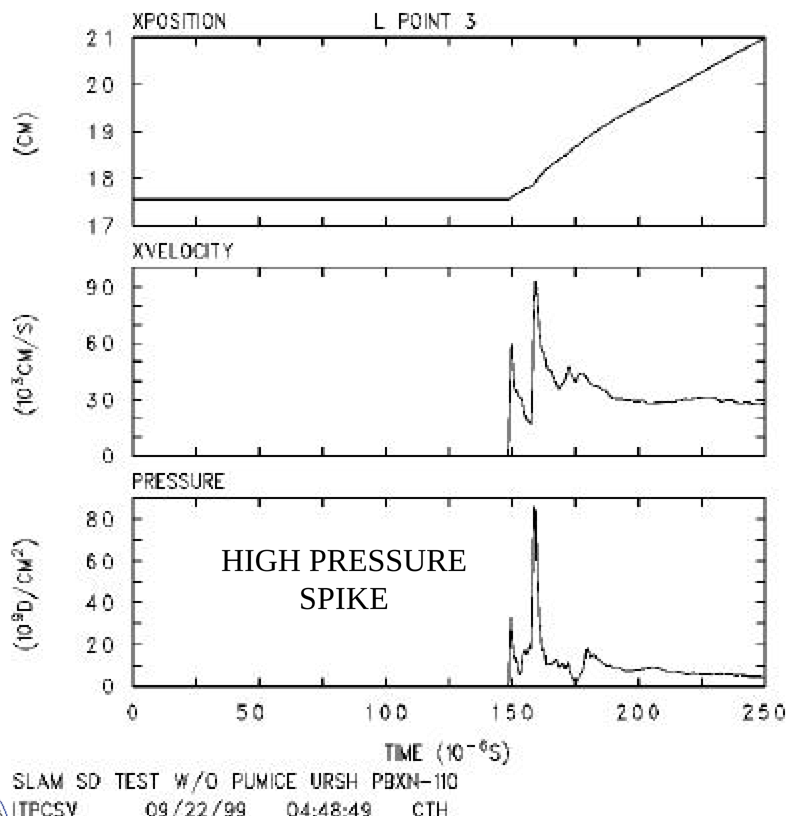
- Hydrocode model predicted no reaction

CTH model material and pressure plots

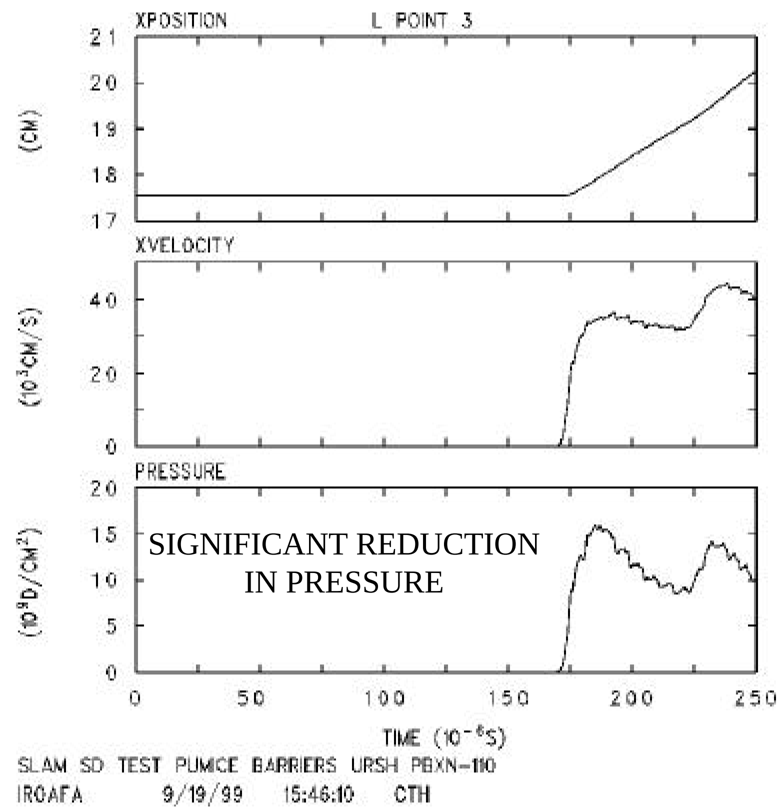


SLAM ER Tandem Warhead
SD Model

<u>CTH RESULTS</u>
<u>WITHOUT PUMICE</u>
(Explosive and case interface)

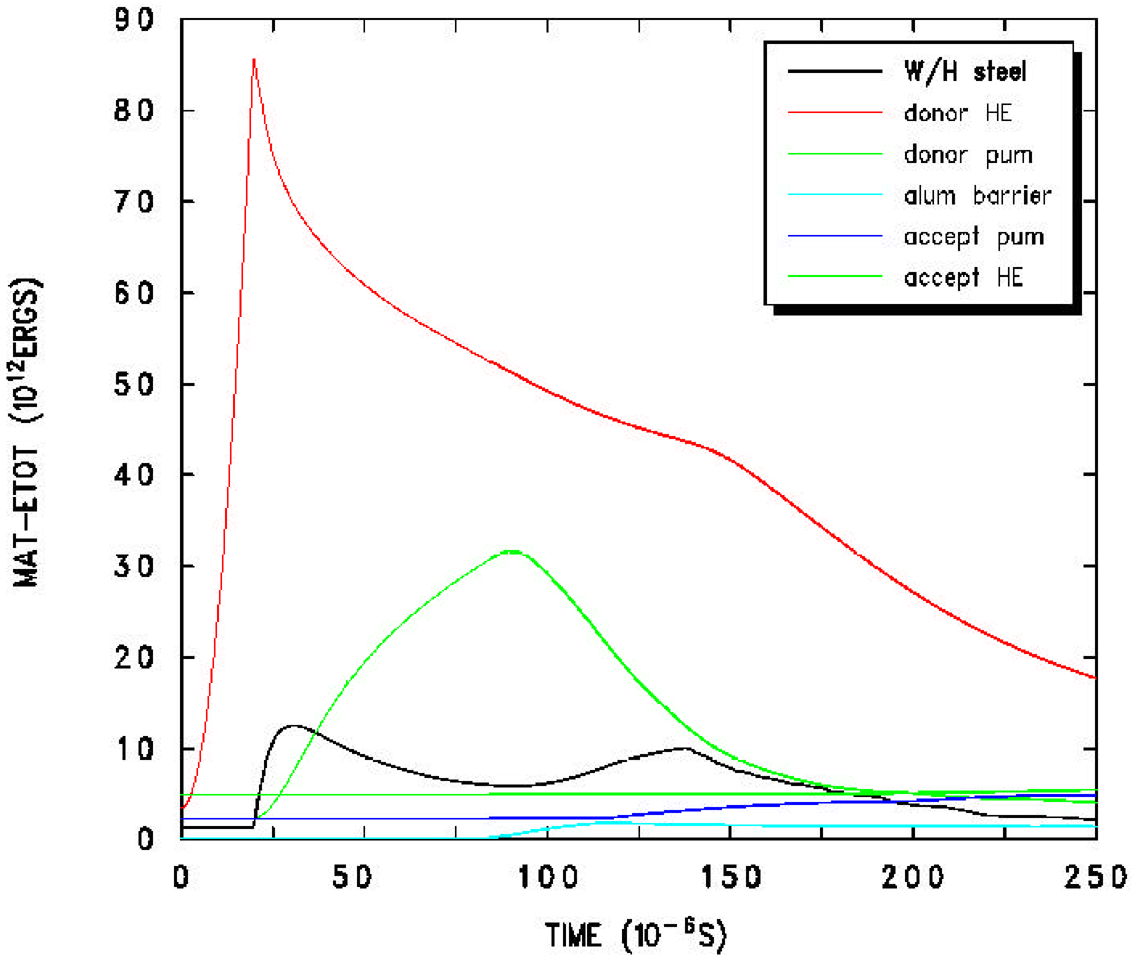


<u>CTH RESULTS</u>
<u>WITH PUMICE</u>
(Explosive and case interface)



SLAM ER Tandem Warhead SD Model

- Donor and acceptor pumice absorbed 43% of warhead energy



Potential Pumice Applications

- Ordnance packaging for use onboard ship
  - Fuzes/boosters stored in pumice containers on bomb pallets
- Magazine areas onboard ship
  - Store more ordnance in same amount of space
- Weapon handling equipment onboard ship
  - Reduce injury and damage caused by accidental initiation

<u>Improve logistical efficiency and optimize use of magazine space onboard ship</u>

Potential Pumice Applications

PUMICE

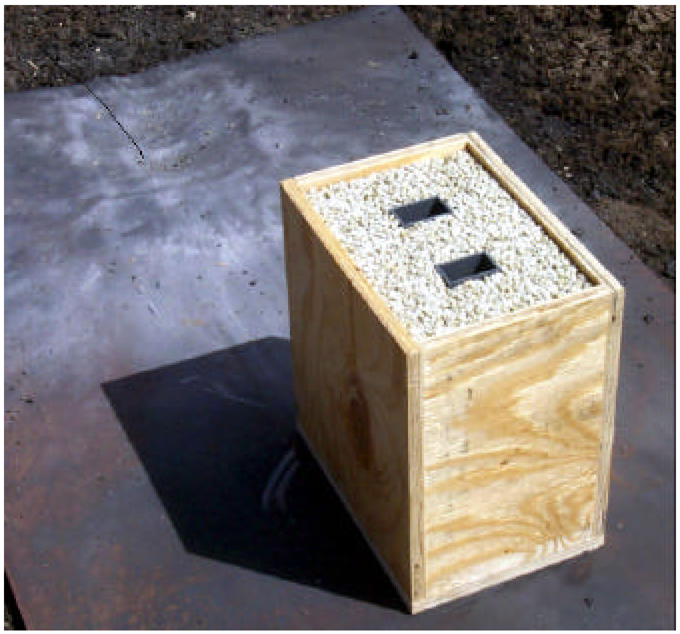
- Thermal barrier for fire protection onboard ship
- Weapon vertical launch system (VLS)
  - Protection from sympathetic detonation as well as thermal protection from fire and cookoff
- Additional work being conducted for use in land based explosive magazines
- Anti-terrorist applications where pumice is incorporated into barriers around buildings

System Level Impact from Pumice

- Design space inside the weapon container for incorporation of the required amount of pumice
- Increased container weight (~ 5% - 10%)
  - Aluminum required to contain the pumice was bulk of the weight
  - Flexible-foam pumice configuration may eliminate need for aluminum
- Increased cost of container (~ 5% - 10%)
  - Fabrication of aluminum required to contain the pumice was bulk of cost increase
  - Increase thermal insulation of weapon system from high temperature exposure

<u>Minimal weight and cost impact due to incorporation of pumice</u>

C-4 Explosive Standoff Tests

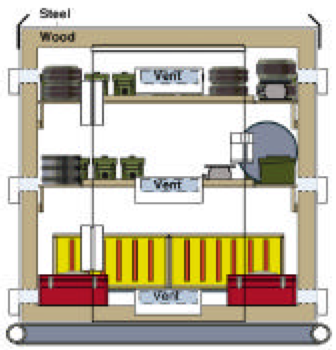


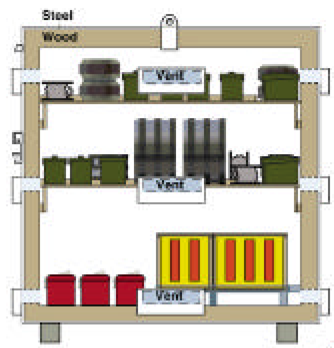
2.5 Pounds of C-4
No Reaction from Acceptor C-4 Block

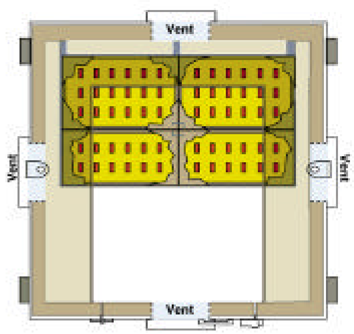
- Determine Standoff for Full Block of C-4 Explosive
- Validate Standoff with Multiple Blocks of C-4

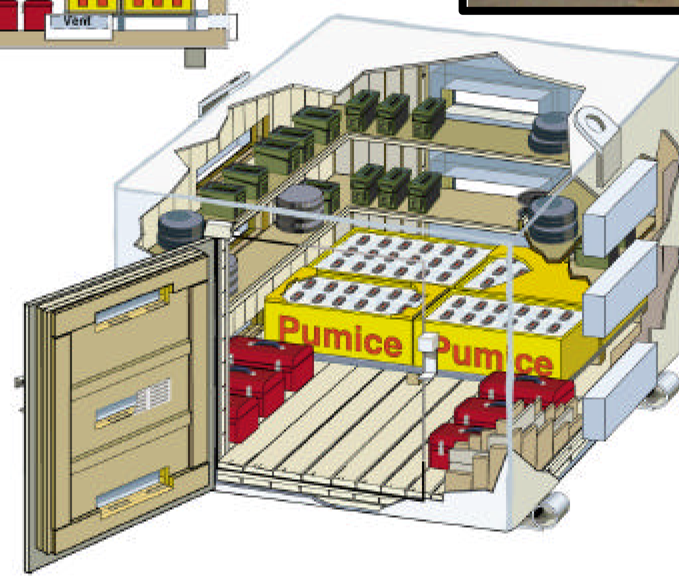
Bottom of Plywood Box

EOD Kit Demonstration Test Setup



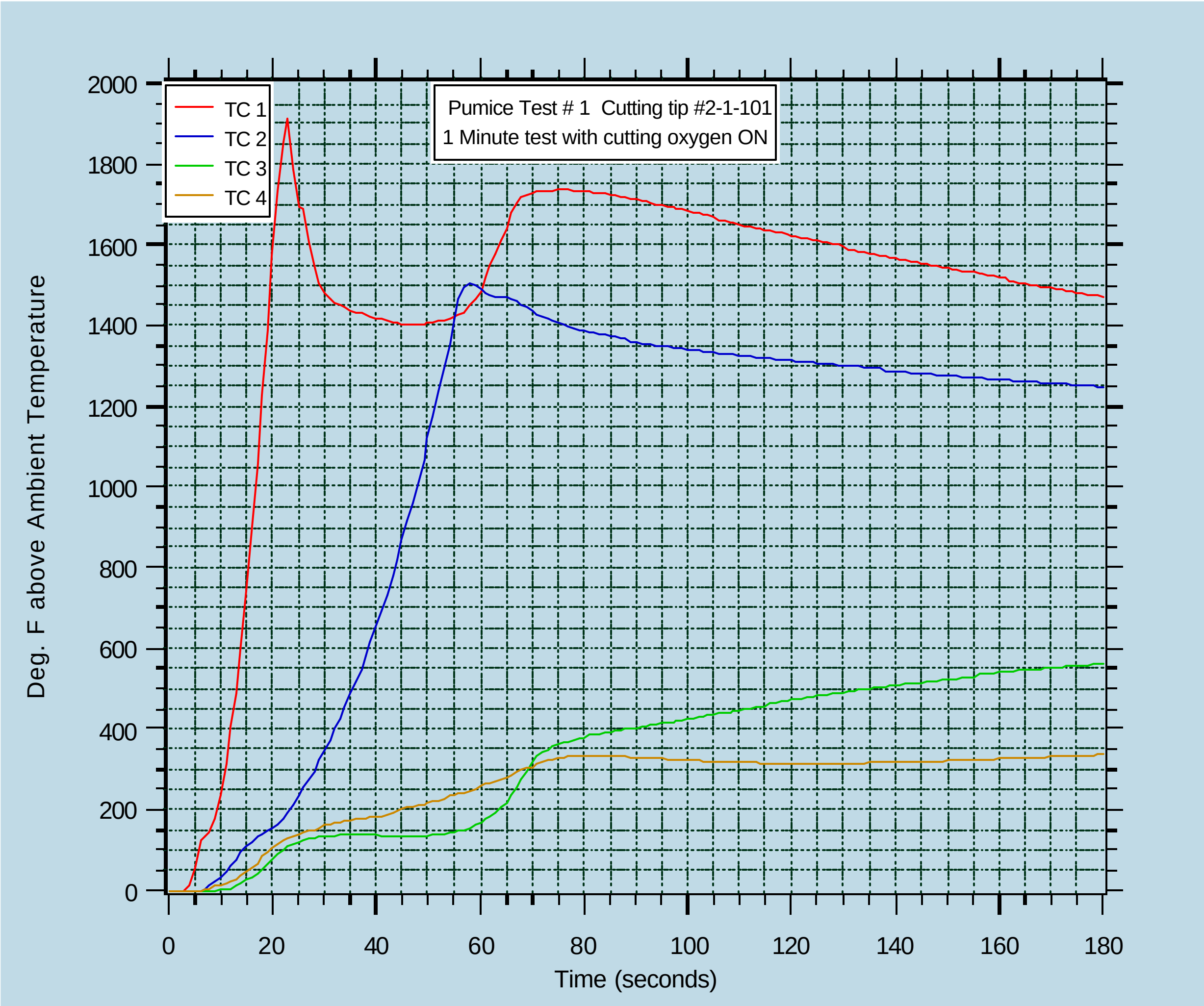






UNCLASSIFIED

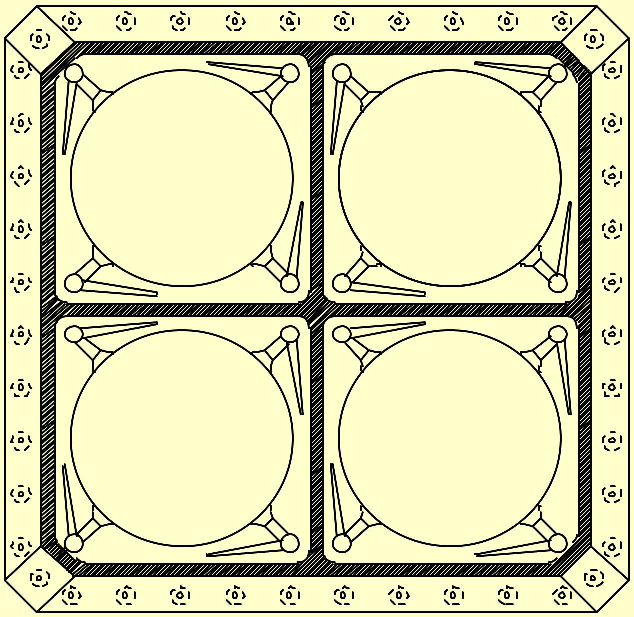
Thermal Barrier

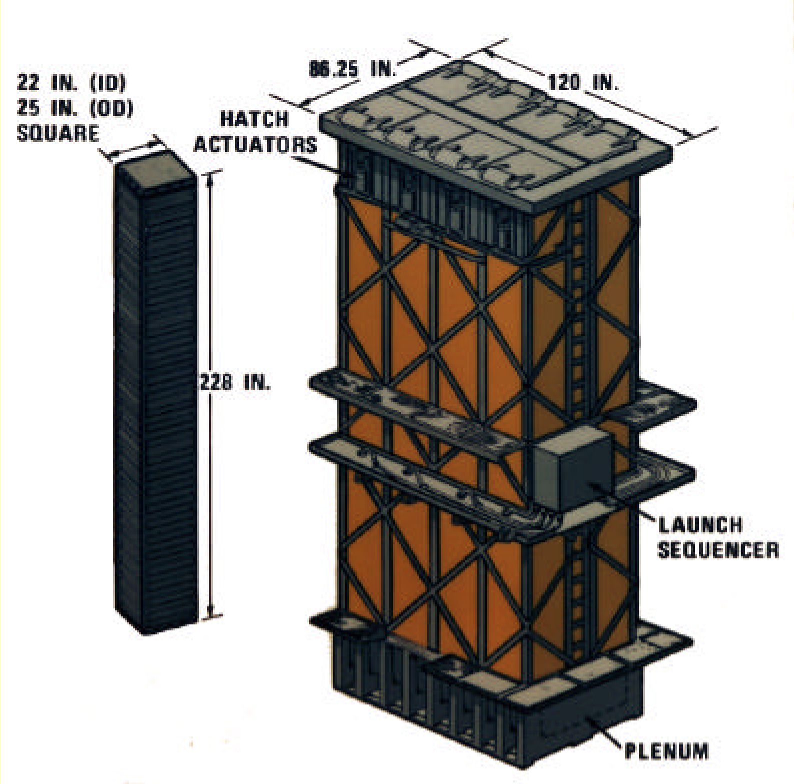


UNCLASSIFIED

PATENT CAUTION
MAY CONTAIN PATENTABLE MATERIAL. TO BE RELEASED ONLY UPON SPECIFIC WRITTEN AUTHORIZATION FROM NAWCWD, CHINA LAKE, CA

VLS



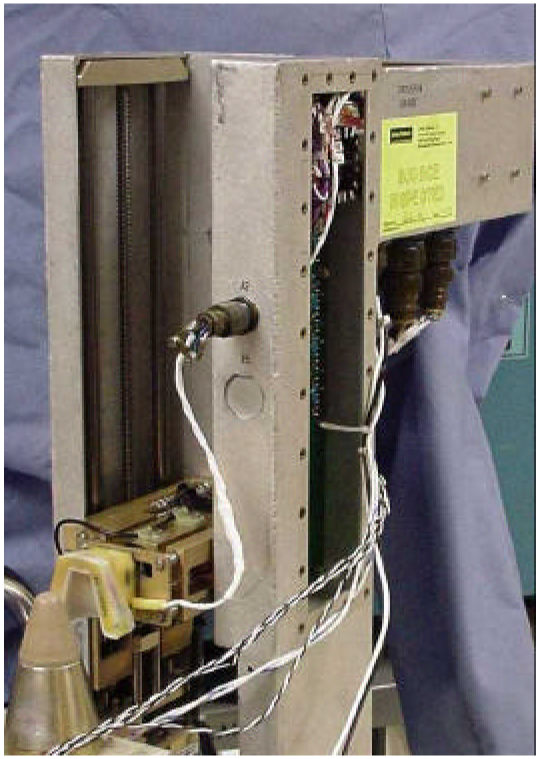

22 IN. (ID)
25 IN. (OD)
SQUARE
HATCH
ACTUATORS
86.25 IN.
120 IN.
228 IN.
LAUNCH
SEQUENCER
PLENUM

Developing an Automatic Inductive Fuze Setter for Crusader

PEO GCSS

CRUSADER

Presented By:
Bob Keil
Alliant Techsystems
Technical Director
Tom Kilian
United Defense L.P.
Technical Director

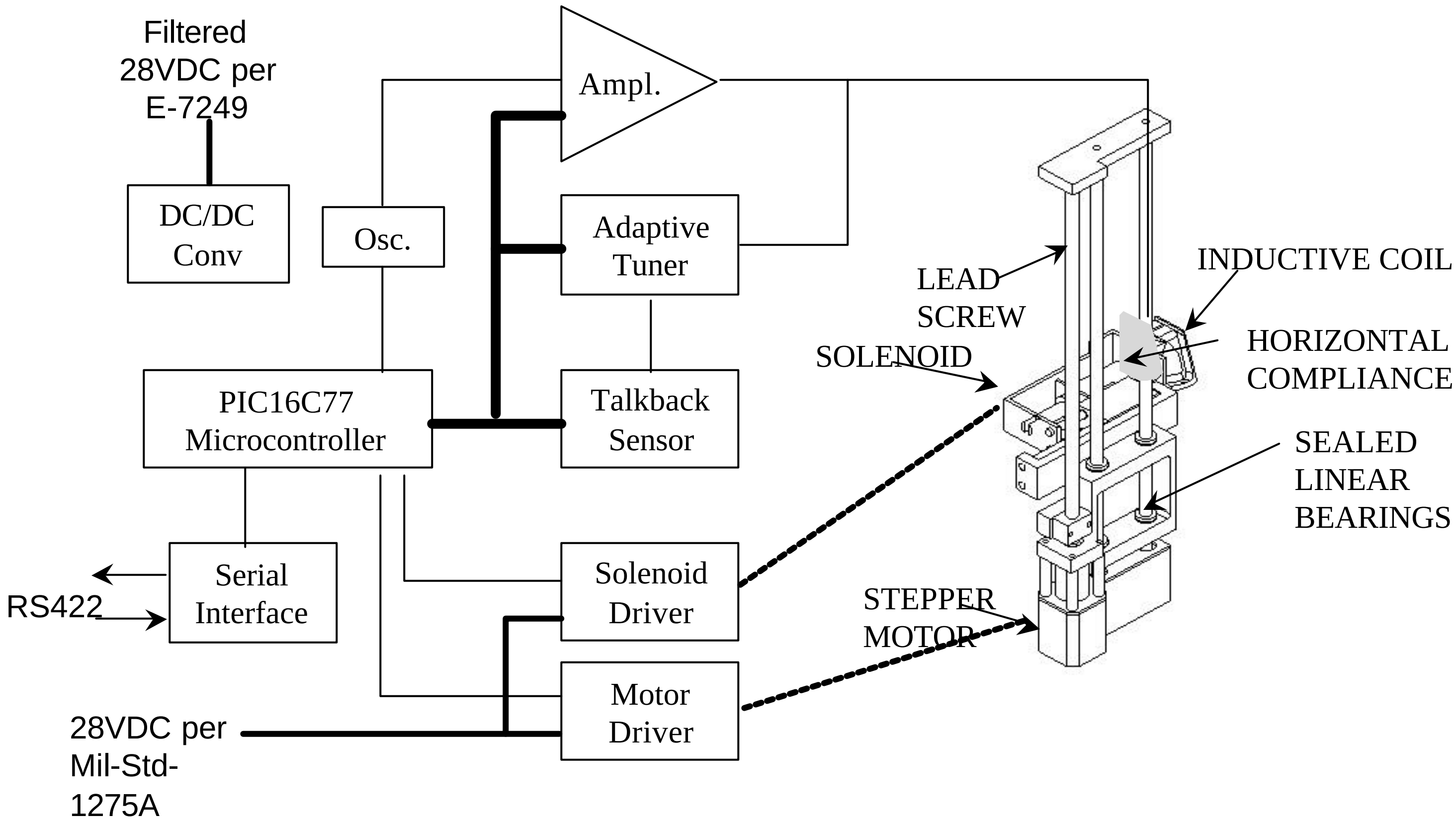


Developing an Automatic Inductive Fuze Setter for Crusader

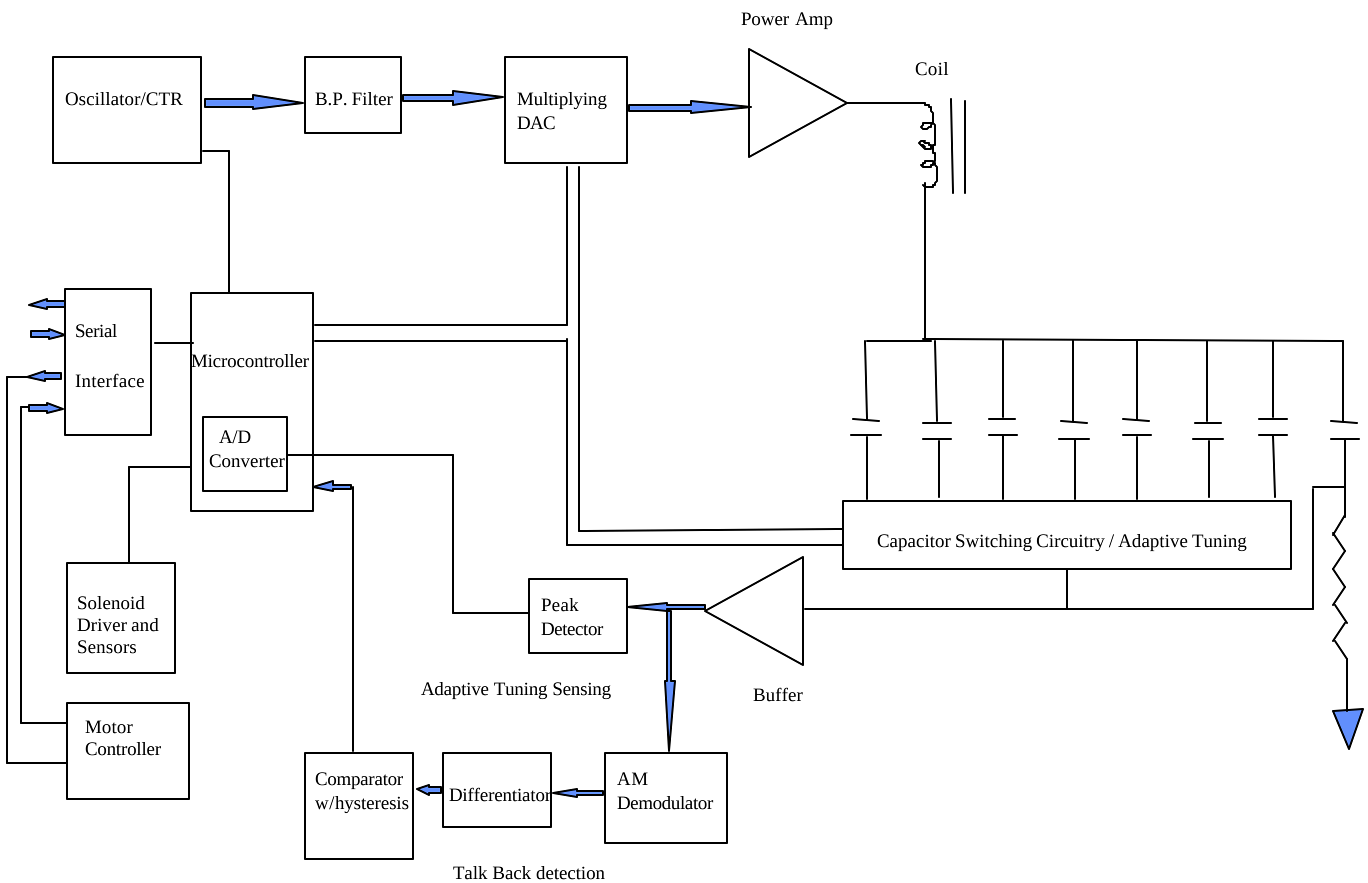
Outline

- Block Diagram of Crusader Fuze Setter
- Coil Positioning Mechanism
- Coil Development
- Coil Driver Circuit
- Talk Forward Control
- Talk Back Receiver
- “NULL” Problem and Solution
- Fuze Message Storage

Block Diagram of Crusader Fuze Setter

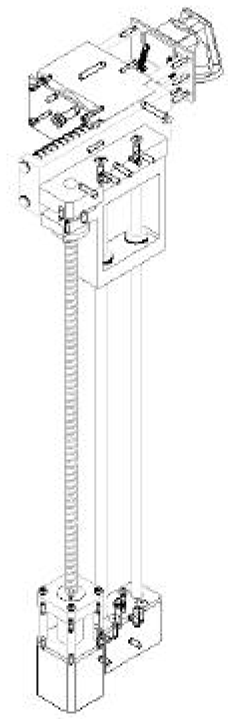


Electronic Block Diagram



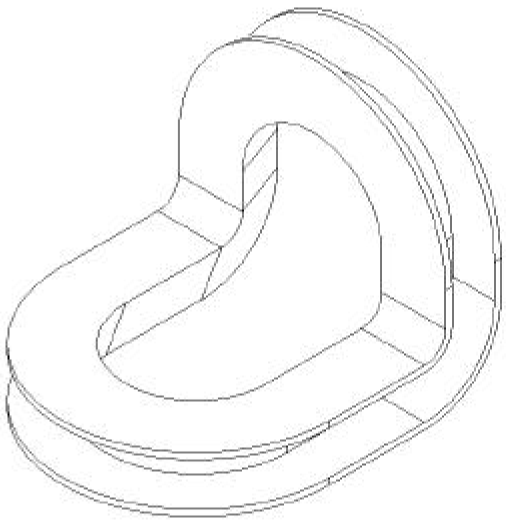
Coil Positioning Mechanism

- **Coil is Positioned for Specific Round**



Coil Development

- **“L” Shaped Coil Form**

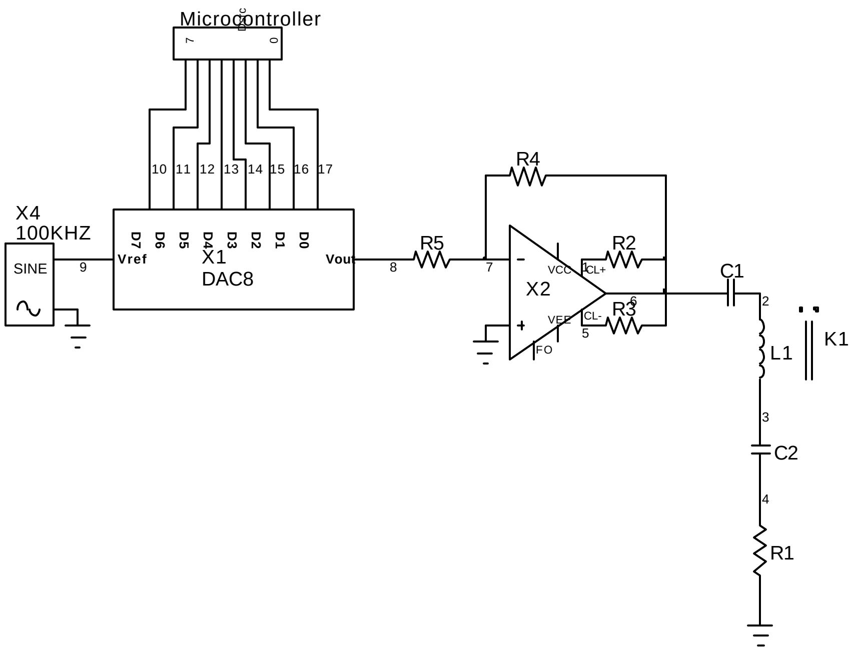


Coil Development

•"L" Coil over M782 Fuze

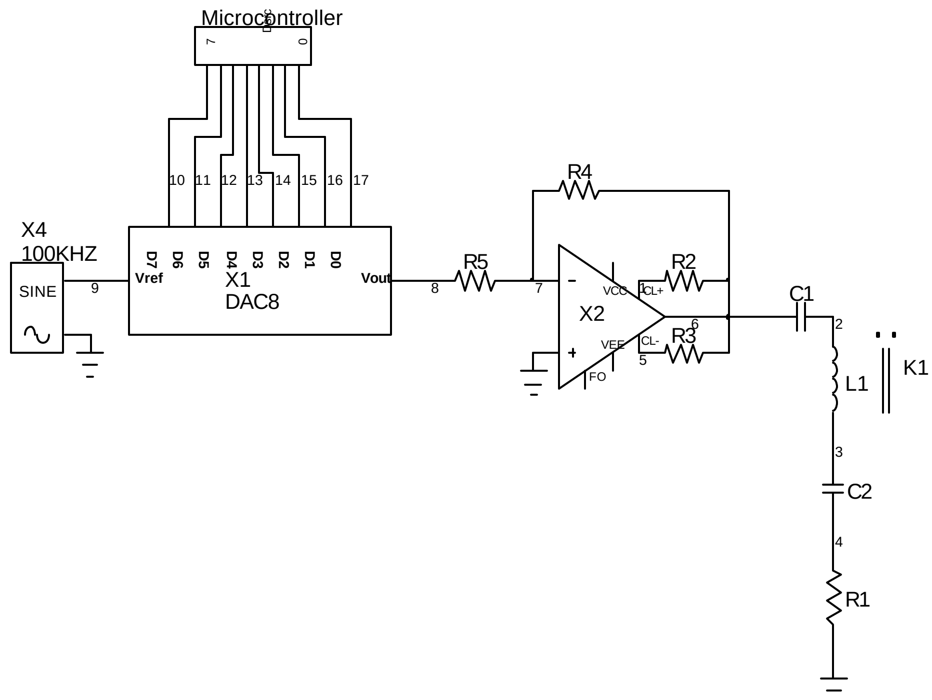
Coil Driver Circuit

- **Power Amplifier**
- **Multiplying D/A**
- **Exponential Decay of Signal**



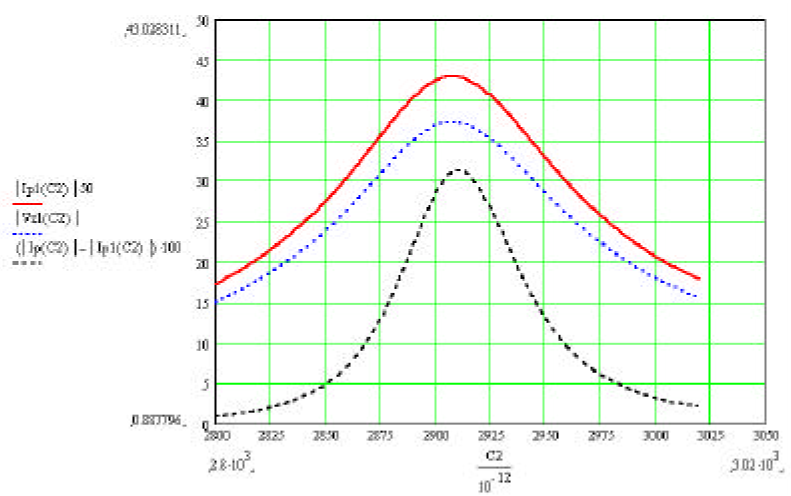
Talk Forward Control

- Multiplying D/A
- 100KHZ Carrier
- Micro-controller generated Digital Word



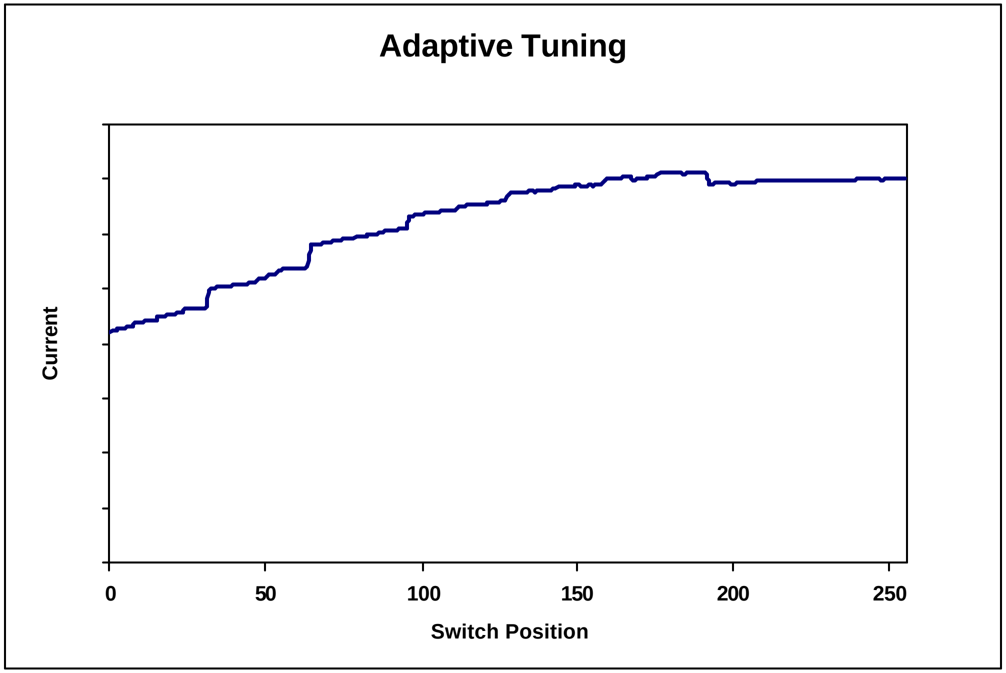
Adaptive Tuning

- **Primary (Setter) Current**
- **Fuze Voltage**
- **Current Difference Signal**



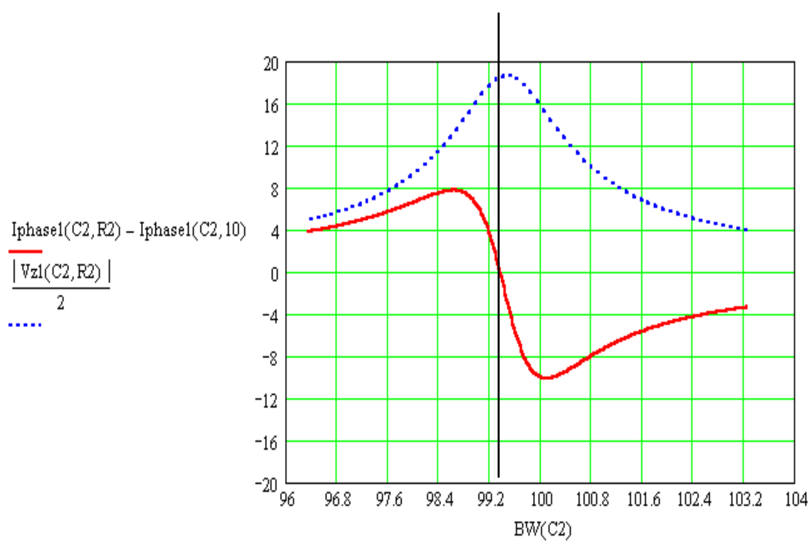
Adaptive Tuning

- **Normalized Data Showing Primary Current During Tuning**

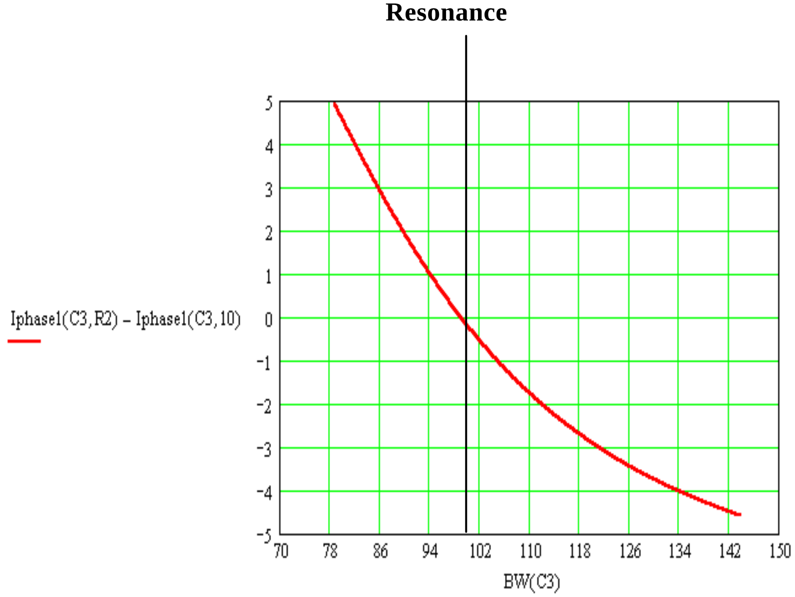


Developing an Automatic Inductive Fuze Setter for Crusader

- **Review of "NULL" Problem**



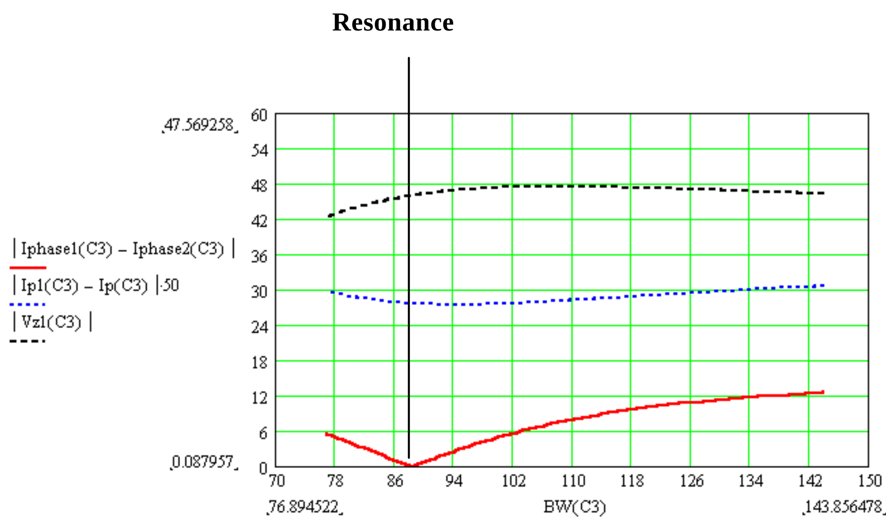
Phase Response and Fuze Voltage Versus Fuze Setter Bandwidth Showing Effect of NULL



Phase Response Versus Fuze Bandwidth Showing Effect of NULL

Solution to “NULL” Problem

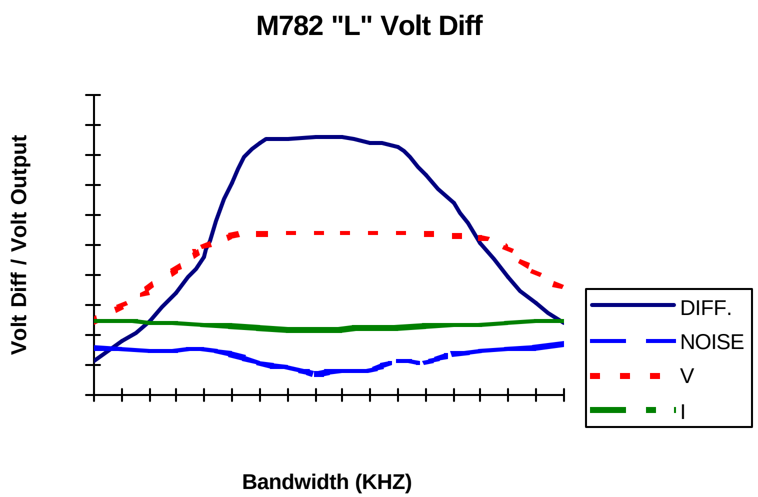
- **Current Difference Method**
- **Solves “NULL” Problem**



Graphical Output of MATHCAD Model Showing Theoretical Phase Difference, Current Difference and Fuze Voltage VS Gap-Bandwidth

Solution to "NULL" Problem

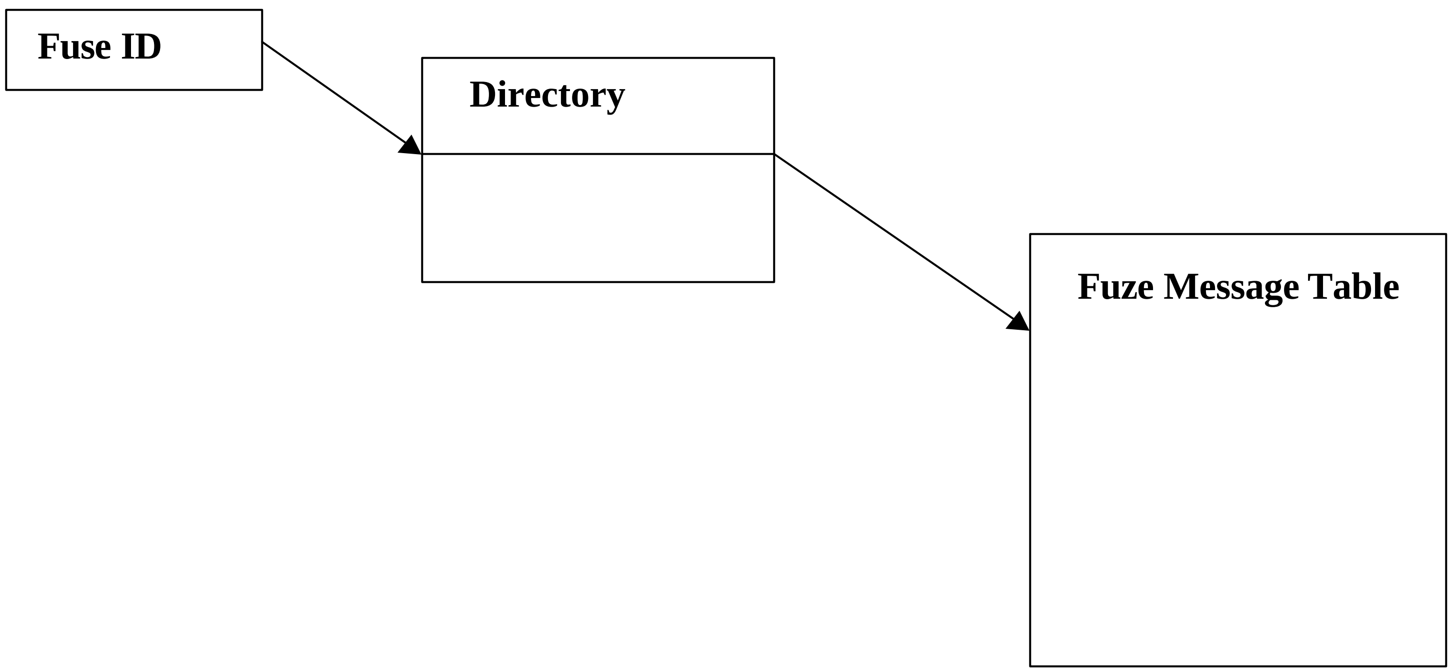
- **Current Difference Method Normalized Data**



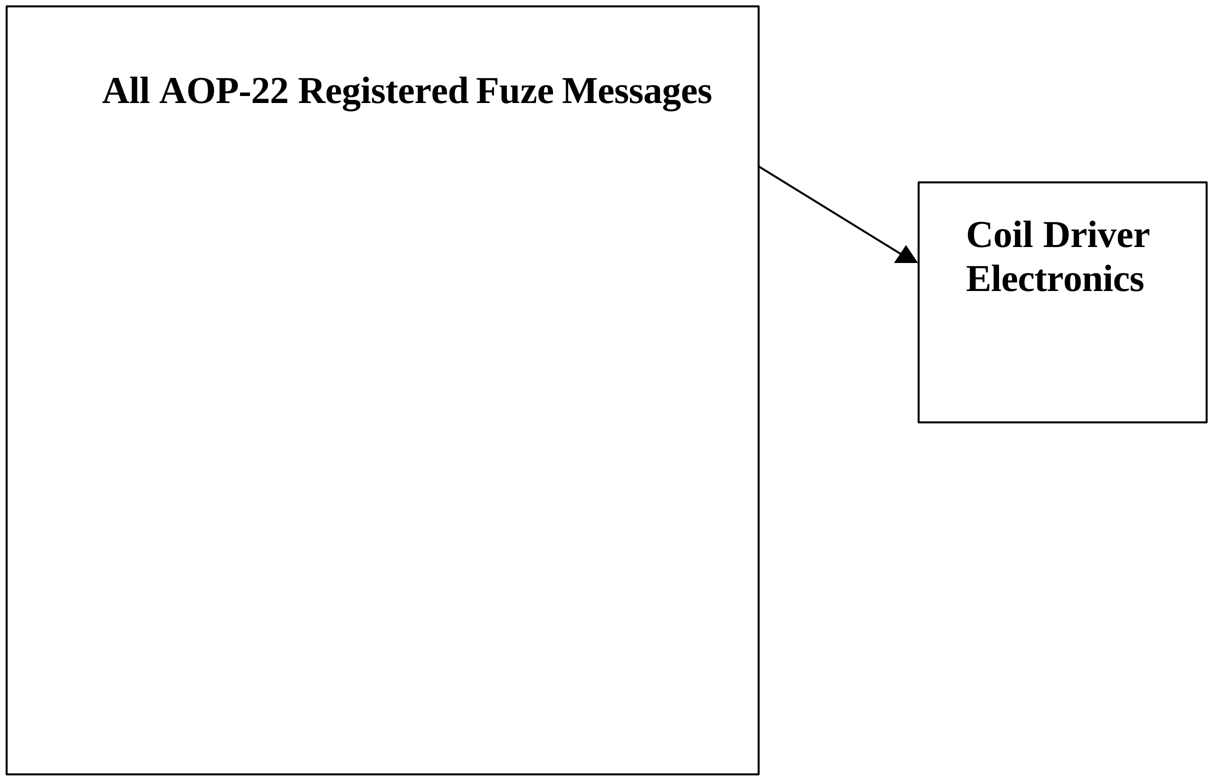
Expandable Fuze Message Memory

- **Program Accesses a Directory Organized by Fuze ID**
- **Directory points to a Table of Messages**

Fuze Message Directory



Fuze Message Table



Summary

- "L" Shaped Coil Developed
- Adaptive Tuning of Resonant Circuit
- "NULL" Problem Solved
- Expandable Fuze Message Storage Scheme

A Viewpoint from OSD

Anthony J. Kress

Staff Assistant

Strategic and Tactical Systems, Munitions

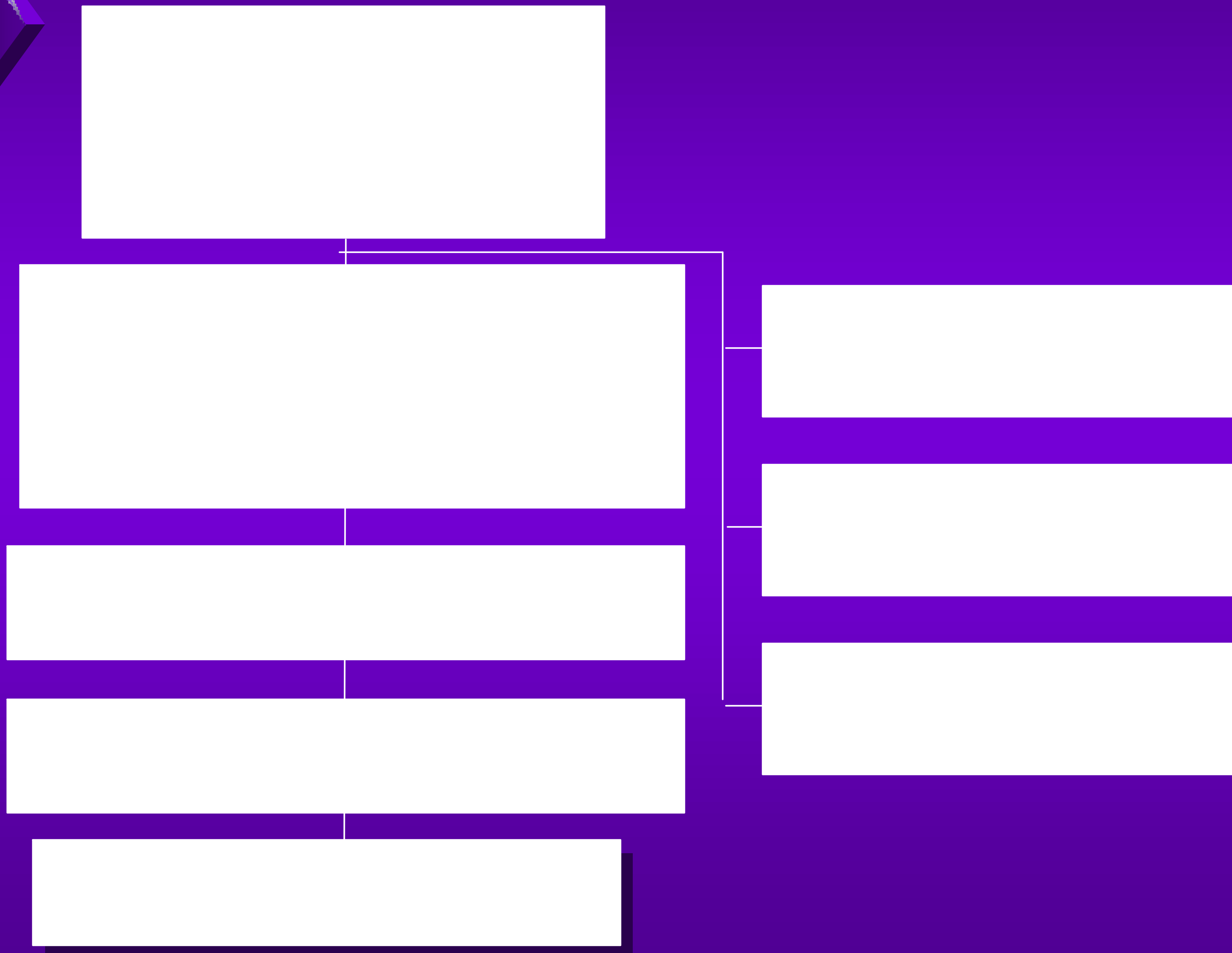
OUSD (A&T)/S&TS/OM
Room 3B1060
3090 Defense Pentagon
Washington, DC 20301-3090

(703) 695-7756
DSN 225-7756
Fax (703) 614-3496
E-Mail:kressaj@acq.osd.mil

BRIEFING FLOW

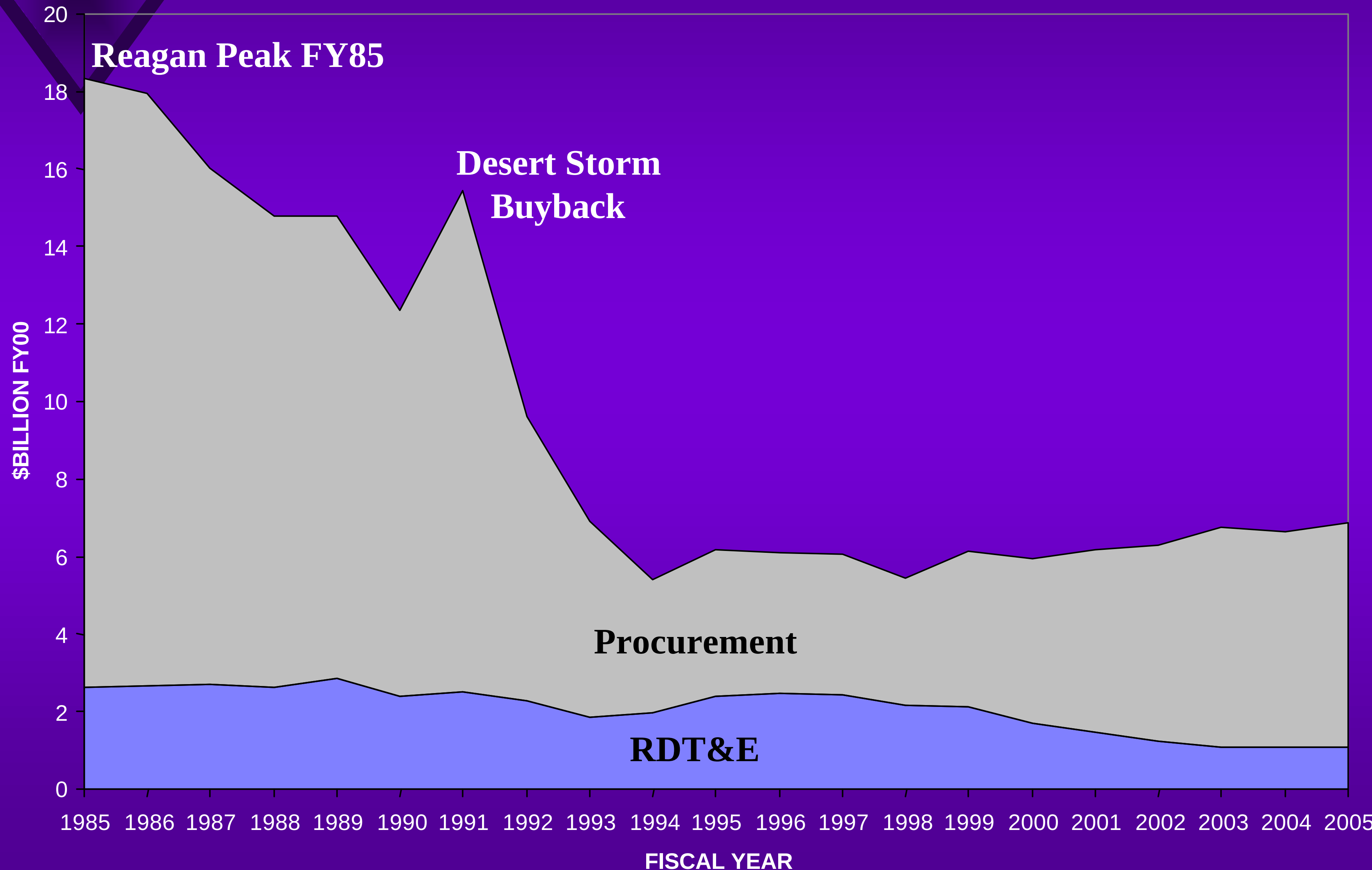
- DoD Organization
- Fiscal Trends
- Unexploded Ordnance Study
- Conclusions

DoD ORGANIZATION



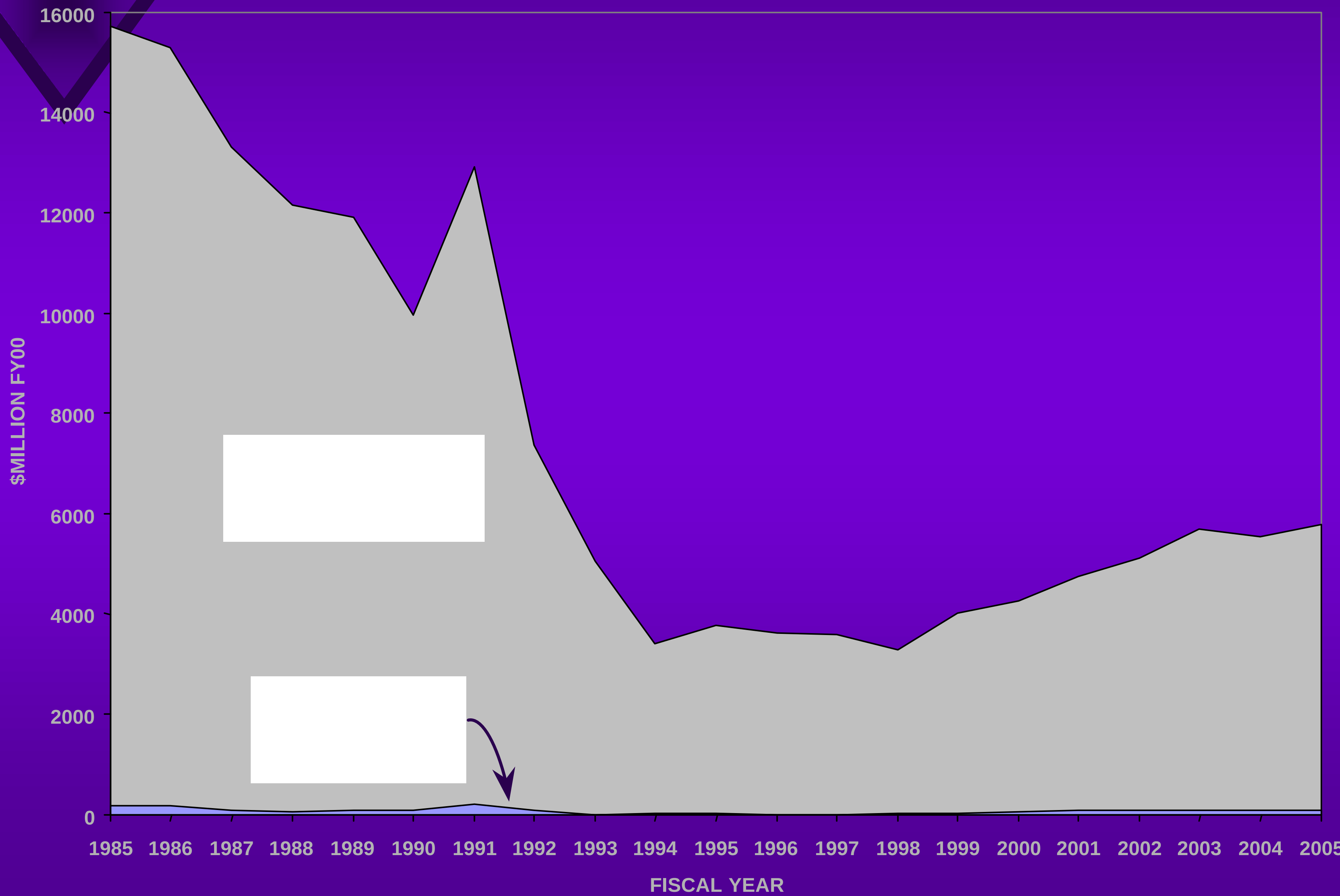
FISCAL TRENDS

Total Munitions RDT&E and Procurement



FISCAL TRENDS

Total Munitions and Fuze Procurement



UNEXPLODED ORDNANCE STUDY

FY00 AUTHORIZATION LANGUAGE

The <u>House Report 106-162</u> accompanying the <u>National Defense Authorization Act for FY2000</u>, stated the following:

The committee notes that there are a number of apparently duplicative efforts within the Services and Defense-wide programs to pursue self-destruct fuzes for munitions. The Army has recently type-classified self-destruct fuzes for some Army munitions, and yet it appears that there is no Department-wide program development to share the Army's completed development or to coordinate other Service efforts.

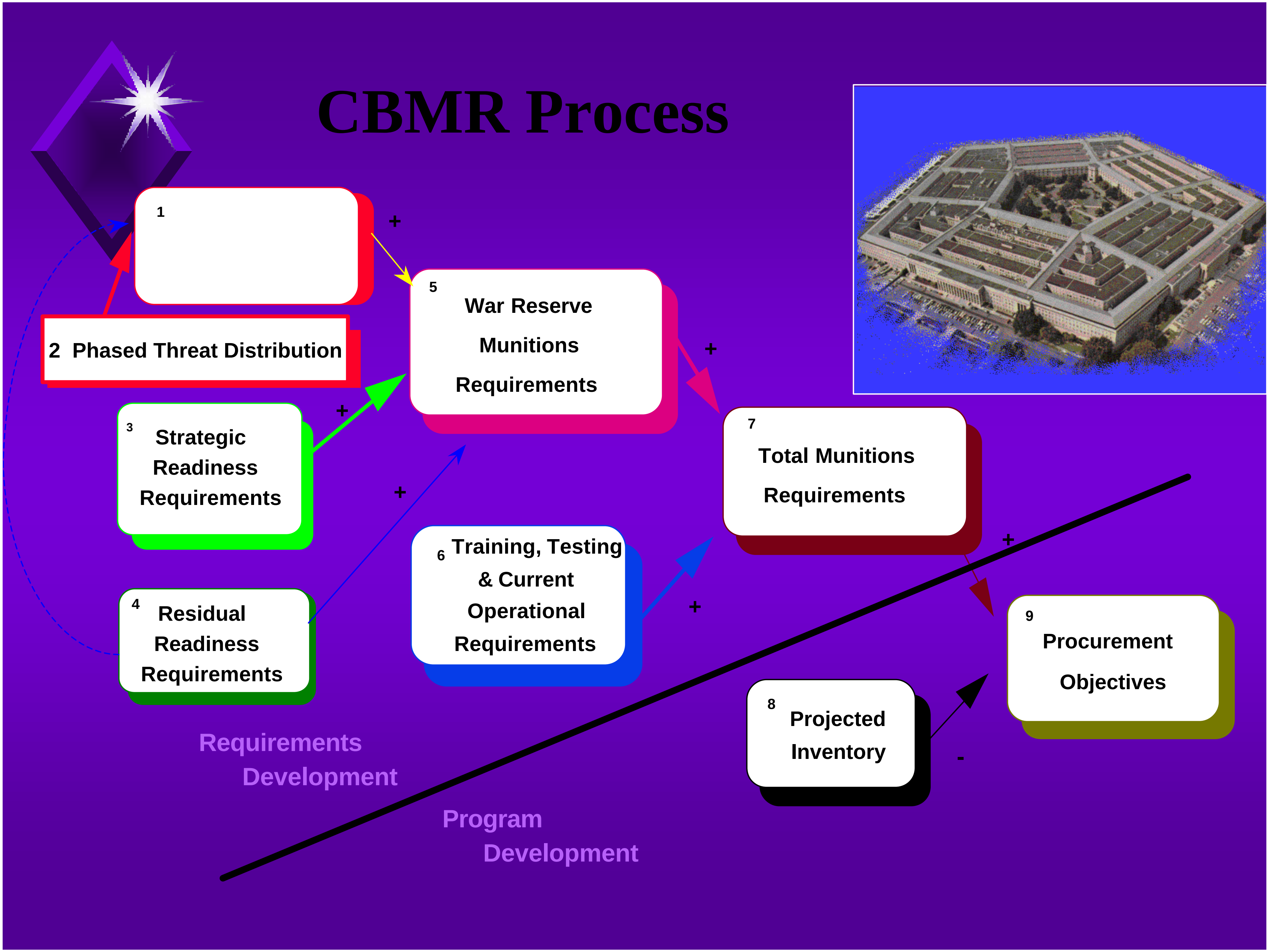
The committee directs that the Secretary of Defense conduct a study of unexploded ordnance problems and establish a Defense-wide program to develop affordable, reliable self-destruct fuzes for munitions, report the results of this study and the actions being taken by December 31, 1999.

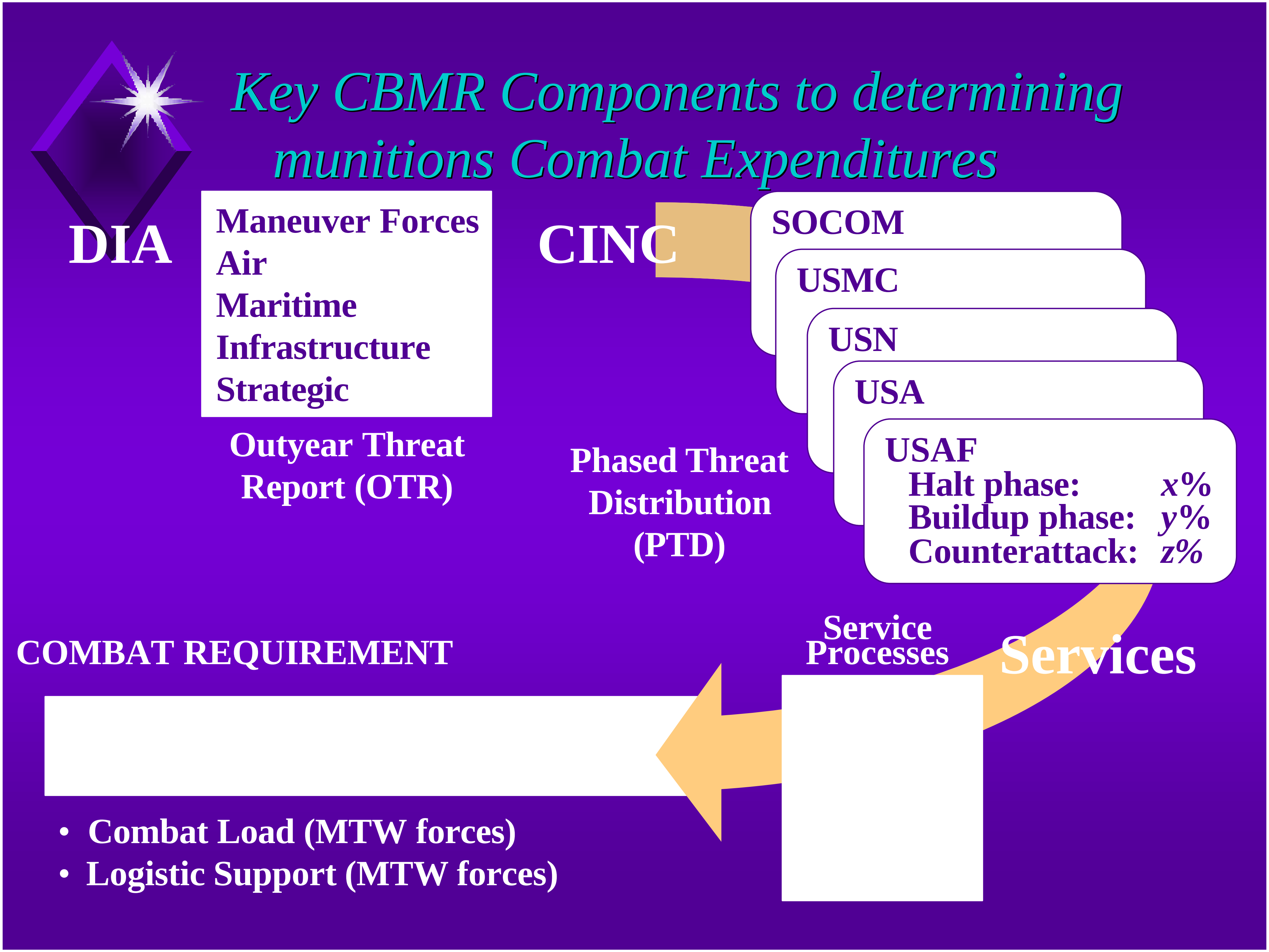
UNEXPLODED ORDNANCE STUDY

FY00 APPROPRIATION LANGUAGE

The House Appropriations Committee, Report 106-244, stated a similar request:

The committee is aware that the Army has completed testing of, and type-classified, M234 and M235 self-destruct fuzes for artillery and rocket grenades. The Committee believes that using a self-destruct fuze in future production of grenades, bomblets and submunitions could reduce the risk of unexploded ordnance casualities on the battlefield. The Committee directs the Secretary of Defense to report to the Committee, no later than December 31, 1999, an analysis of unexploded ordnance issues and recommended solutions to include the use of self-destruct fuzes.


CBMR Process
1
2 Phased Threat Distribution
3 Strategic Readiness Requirements
4 Residual Readiness Requirements
5 War Reserve Munitions Requirements
6 Training, Testing & Current Operational Requirements
7 Total Munitions Requirements
8 Projected Inventory
9 Procurement Objectives
+
+
+
+
+
+
-
Requirements Development
Program Development


Key CBMR Components to determining munitions Combat Expenditures
DIA
Maneuver Forces
Air
Maritime
Infrastructure
Strategic
Outyear Threat Report (OTR)
CINC
Phased Threat Distribution (PTD)
SOCOM
USMC
USN
USA
USAF
Halt phase: x%
Buildup phase: y%
Counterattack: z%
COMBAT REQUIREMENT
Service Processes
Services
• Combat Load (MTW forces)
• Logistic Support (MTW forces)

Study Results and The Way Forward

- This analysis indicates that numerous unexploded submunitions would be left on the 2-MTW battlefields.
- Study Results briefed at the Department's 2000 Weapons Technical Area Review and Assessment (TARA).
- Weapons TARA recommended the establishment of a Defense Technology Objective.

Conclusions

Recap

- Congressional Language
- Action the Department is taking
- What the Department has done to date

PEO

GCSS

TEAM
CRUSADER

PORTABLE INDUCTIVE ARTILLERY FUZE SETTER XM1155

AMERICA'S
ARSENAL FOR THE BRAVE

PRESENTED TO THE NDIA FUZE SYMPOSIUM APRIL 12, 2000

TACOM
Mobility and Firepower for America's Army

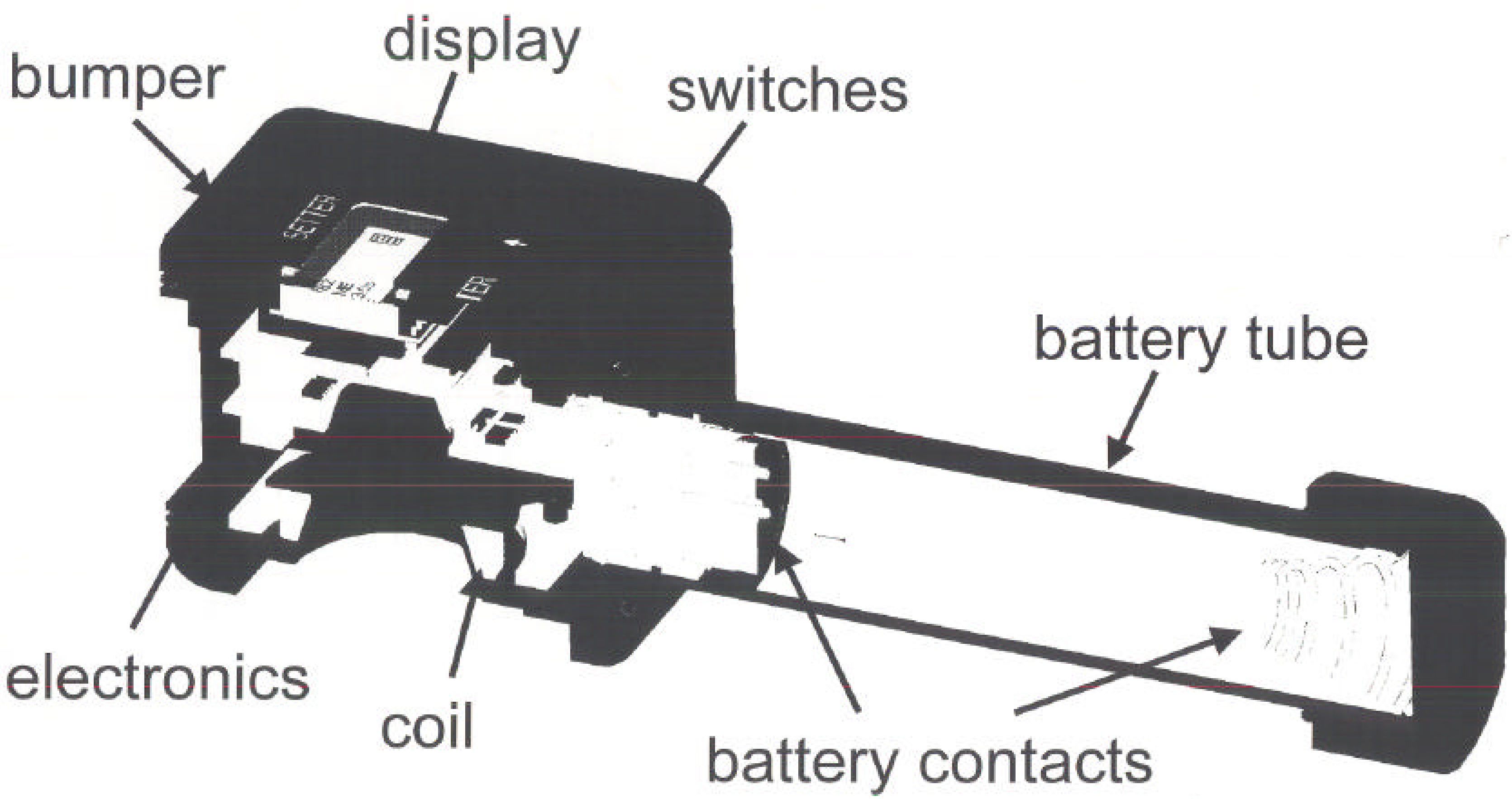
ANDY LESHCHYSHYN
TOM WALKER

Tank-automotive & Armaments COMmand

REQUIREMENTS

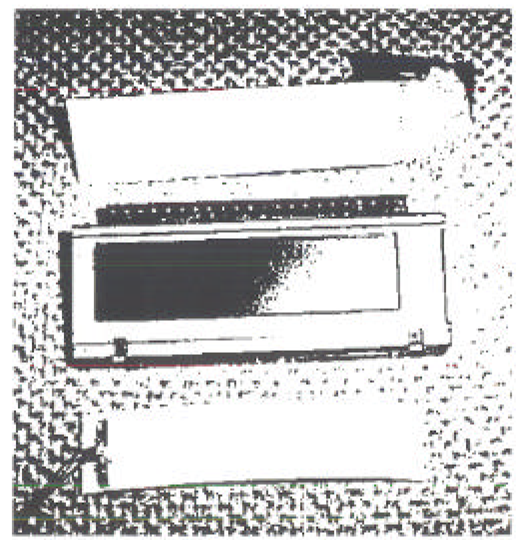
- 400 FUZE SETS @ 20 °C
- -40 TO +63 °C
- MEET NATO INDUCTIVE STANDARD
- HAND HELD, WEIGHT < 8 LBS
- 20 sec OPERATION
- STANDARD "D" BATTERIES
  - » LITHIUM BA-5800 FOR COLD
- SERIAL PORT

ILLUSTRATION

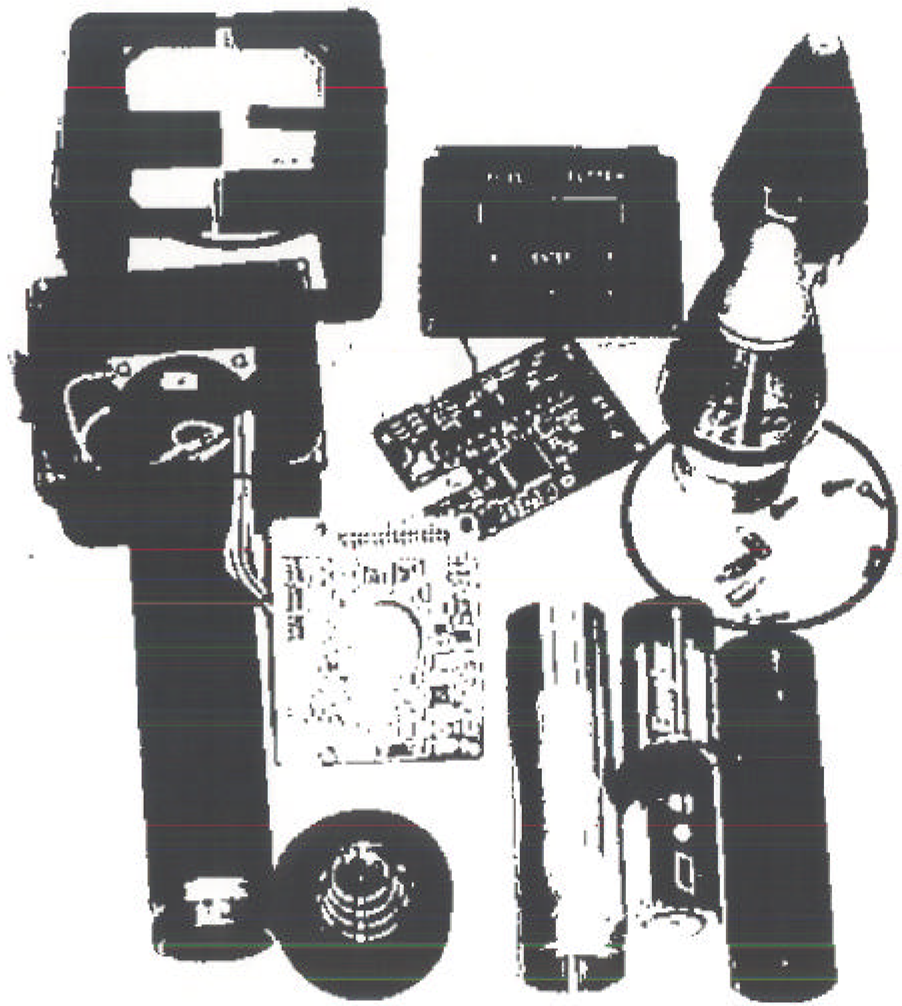


V4 - V5 SETTER CHANGES

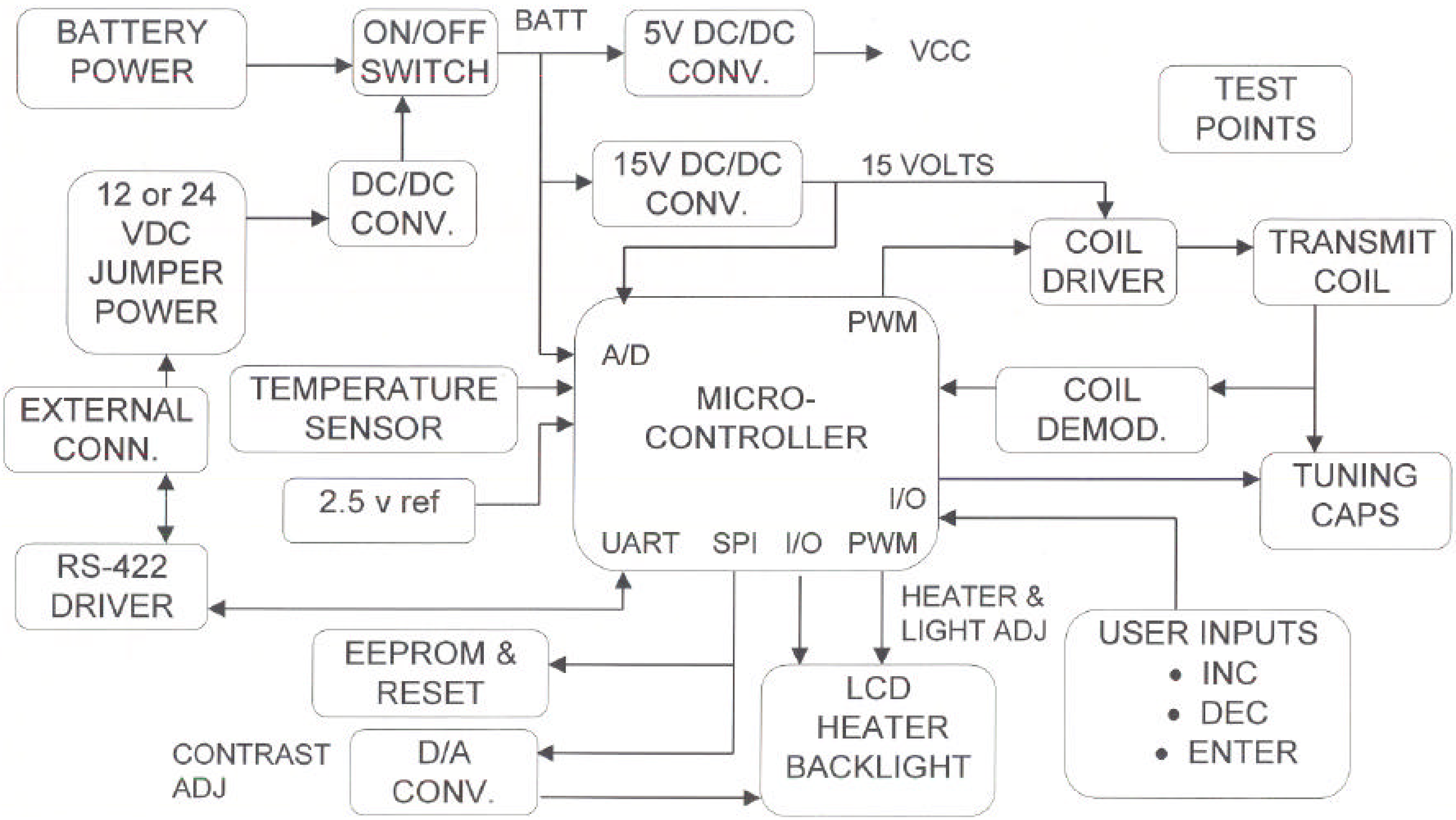
- TACOM-ARDEC to ALLIANT CORP.
- POWER SOURCE
- DELETE BATTERY CHARGER
- LITHIUM ENERGY METER
- MICROCONTROLLER
- DISPLAY
- BACKLIGHT ADJUST
- INTERROGATE



HARDWARE

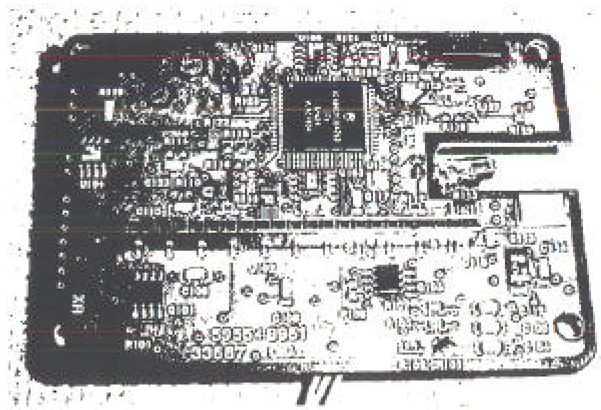


ELECTRONICS

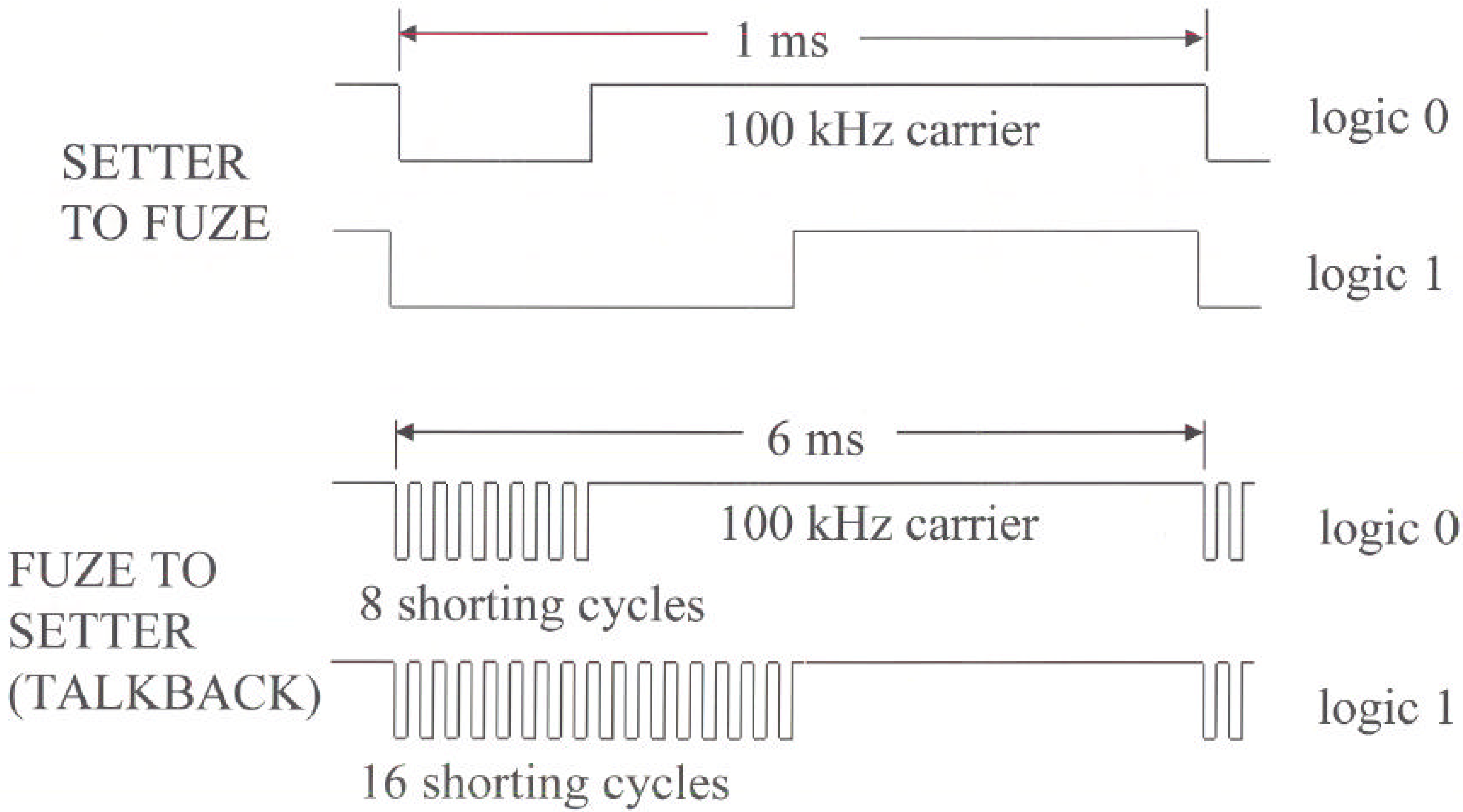


POWER CONSUMPTION

- ELECTRONICS = 250 mW
- DISPLAY & BACKLIGHT = 100 mW
- FUZE SET = 1 W
- DISPLAY HEATER
  - » ALKALINE = 1.4 W
  - » LITHIUM = 4 W
  - » EXTERNAL POWER = 5 W



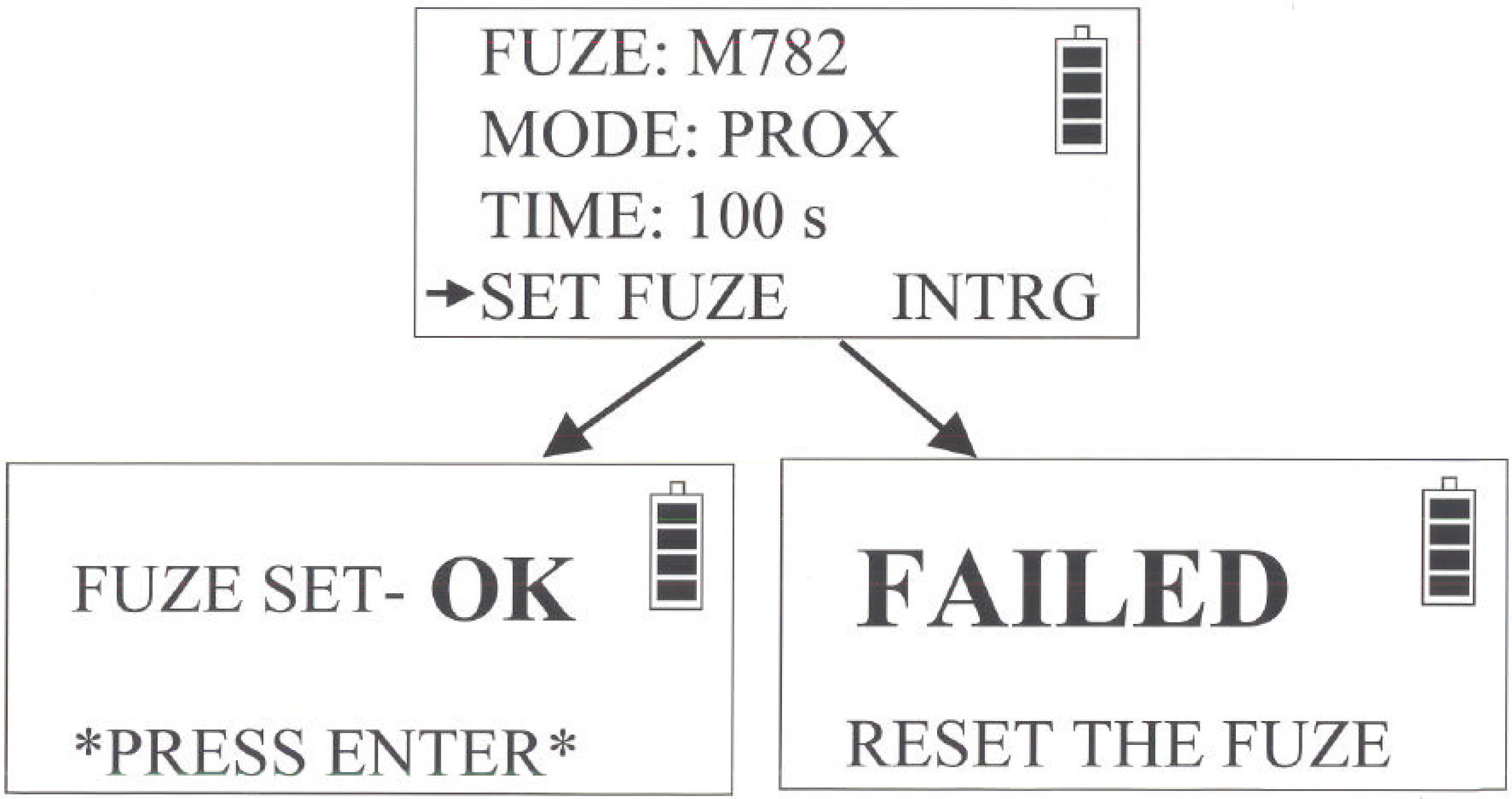
MESSAGE/ STANAG 4369



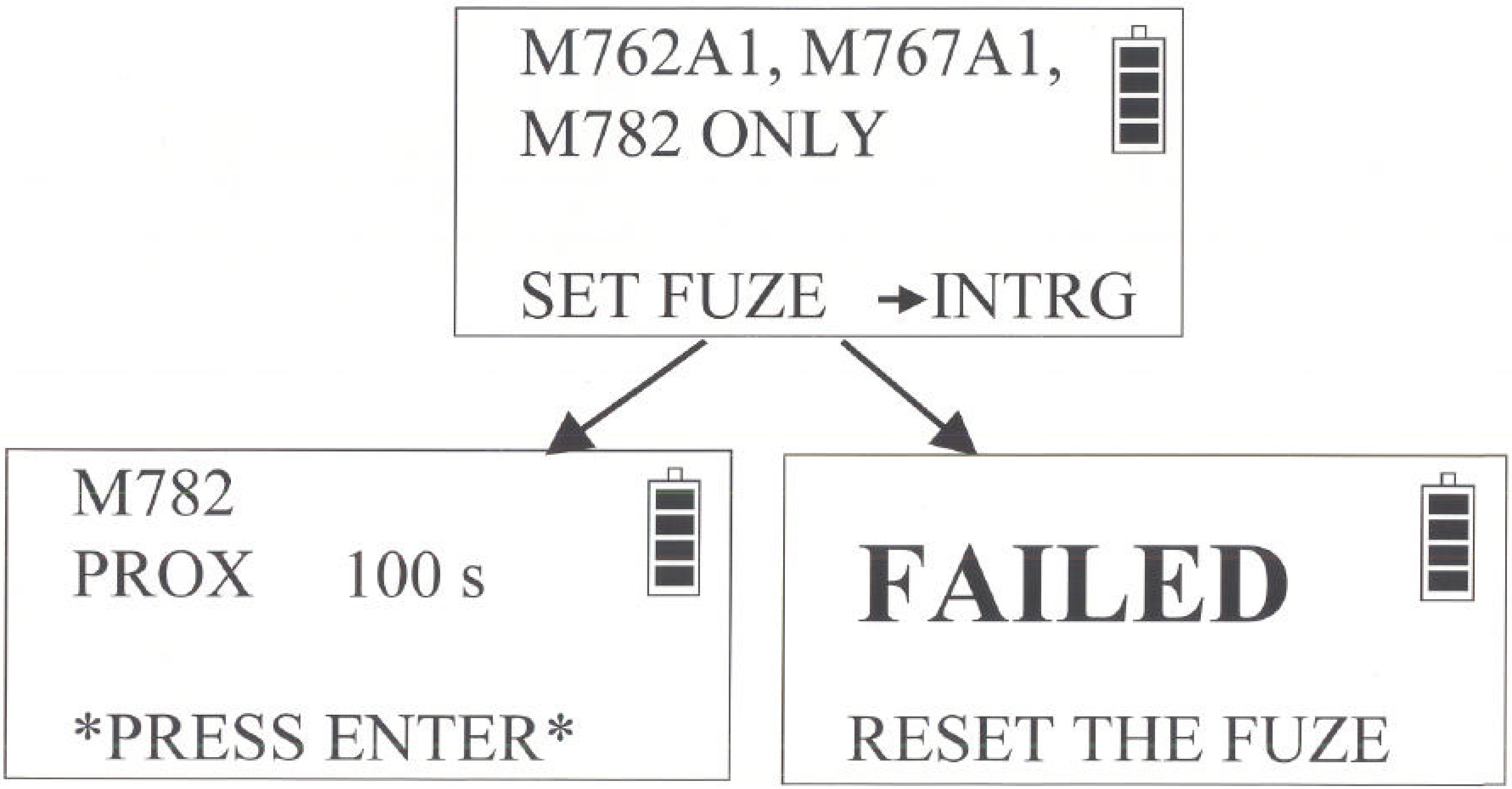
SOFTWARE

- MENU BASED DISPLAY
- SET AND INTERROGATE FUZES
- FUZE HISTORY
- CONTRAST AND BACKLIGHT ADJUST
- SELF TEST
- REMOTE OPERATION
- BATTERY GAGE
- ANSI-C

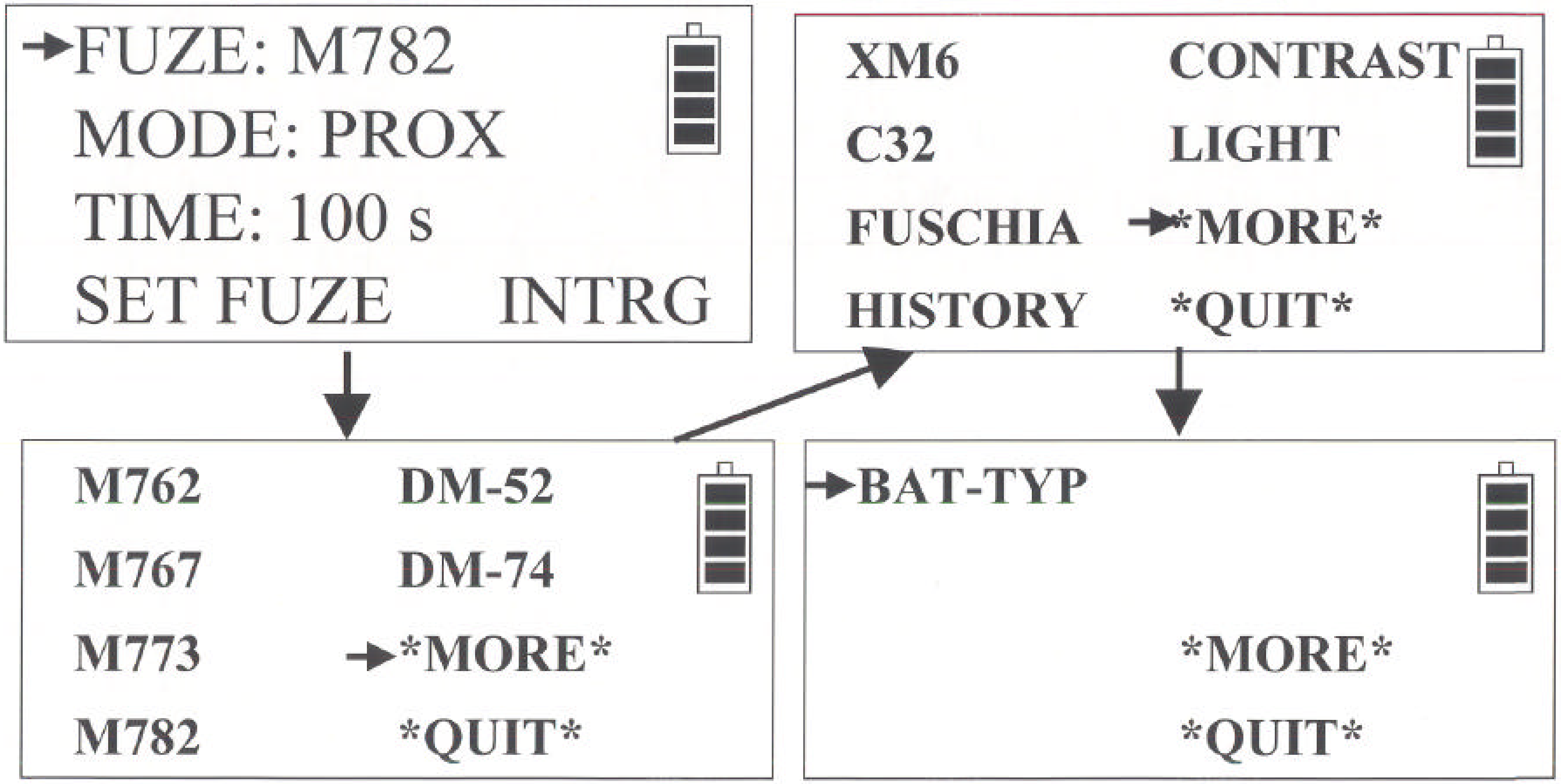
SETTER MENUS



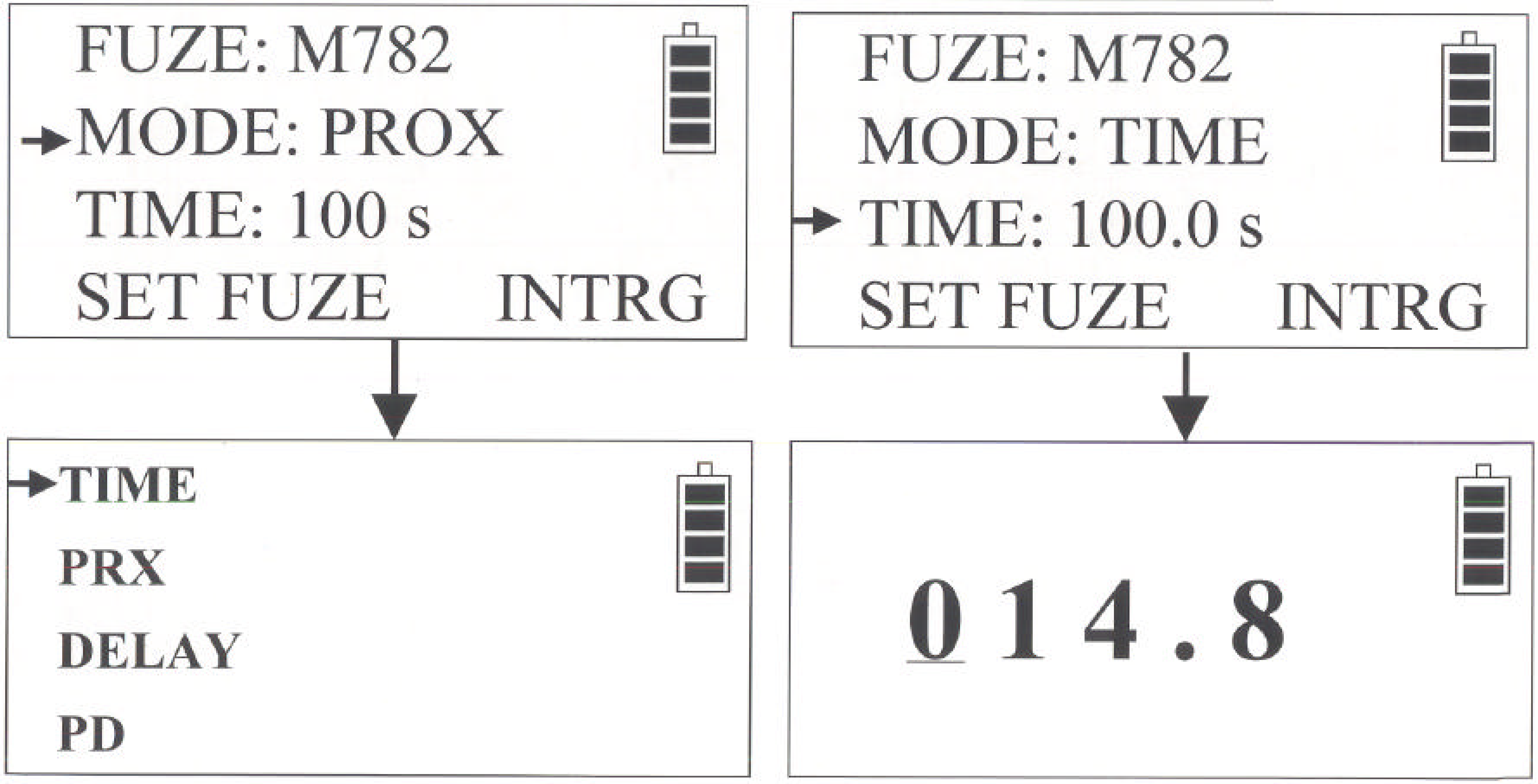
SETTER MENUS



SETTER MENUS



SETTER MENUS



SETTER MENUS

SELECT TYPE :
ALKALINE
→LITHIUM
NICAD

USED LITHIUM
→NEW LITHIUM
(RESETS METER)
QUIT

1ST FUZE BACK
M782
PRX 55 sec
DOWN QUIT UP

2ND FUZE BACK
M762
TIME 75.6 sec
DOWN QUIT UP

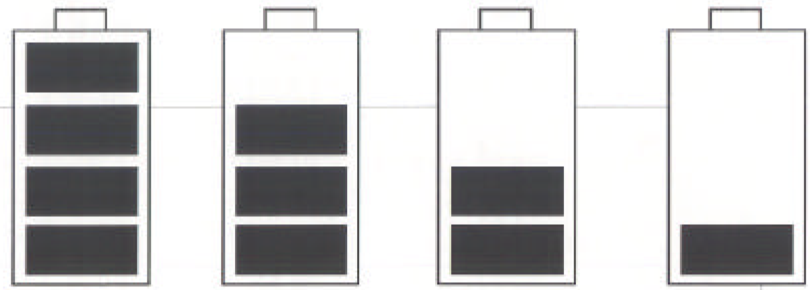
SETTER MENUS

ADJUST CONTRAST
WITH SWITCHES
CONTRAST #58
DOWN QUIT UP

ADJUST LIGHT
WITH SWITCHES
LIGHT #83
DOWN QUIT UP

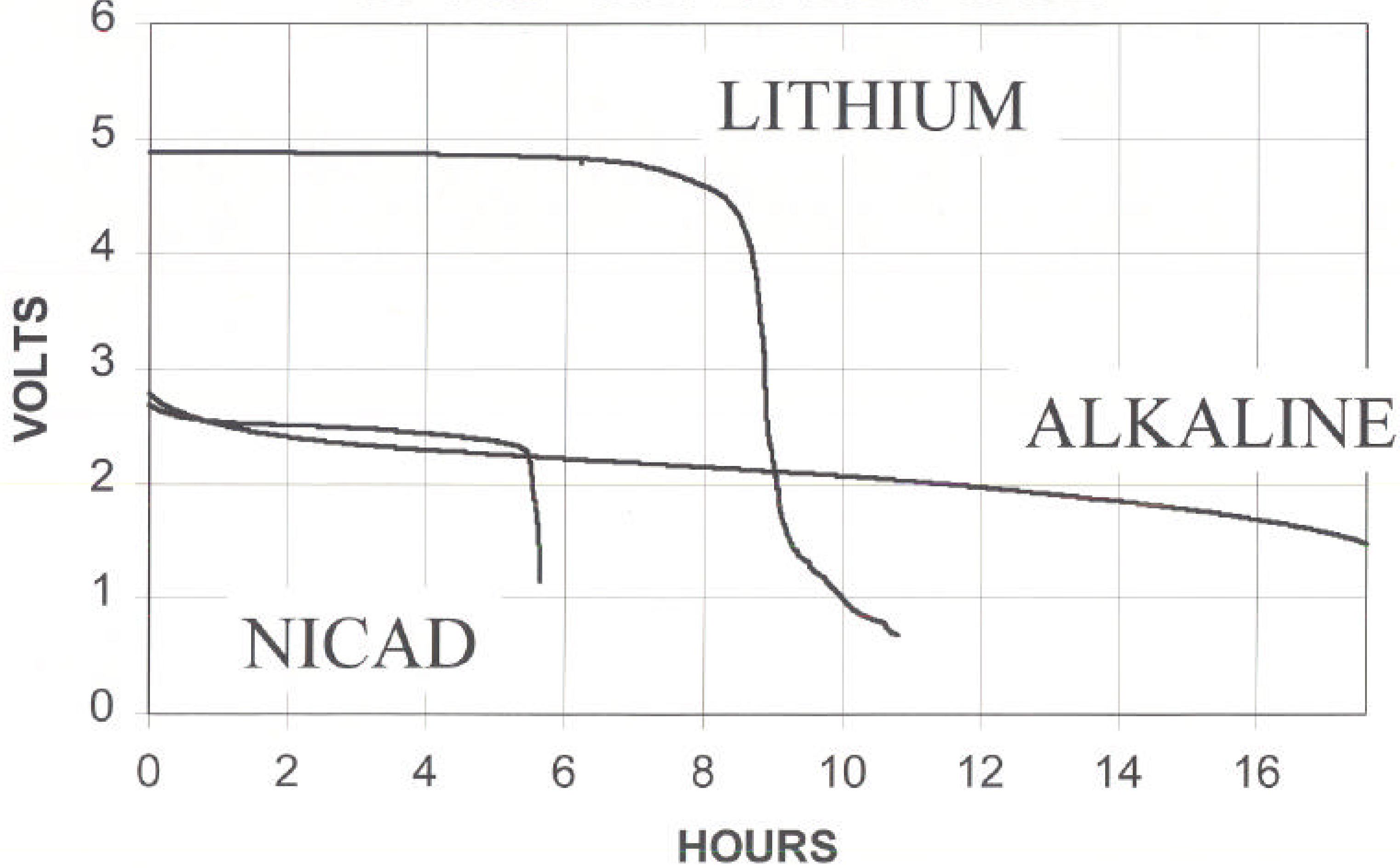
BATTERY GAGE

- BATTERY ICON

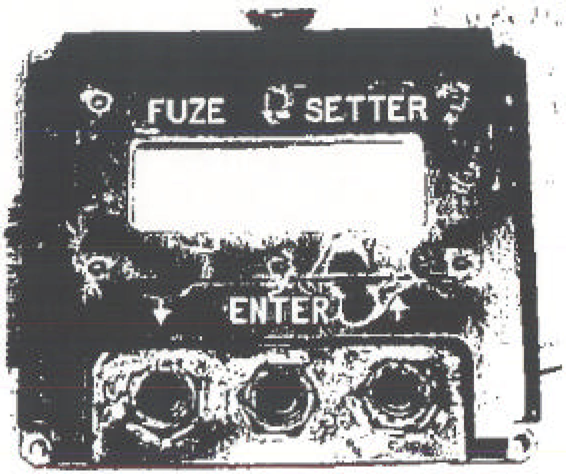


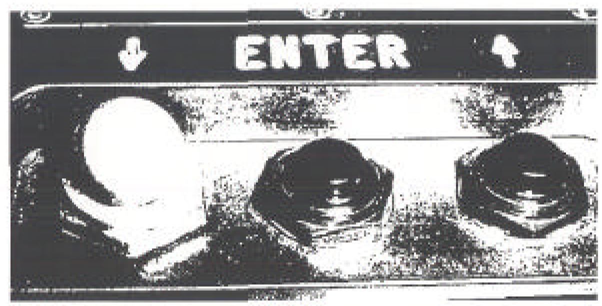
- LITHIUM: ENERGY METER STYLE
- ALKALINE: VOLTAGE & TEMPERATURE
- AVERAGE A/D READINGS
- HYSTERESIS

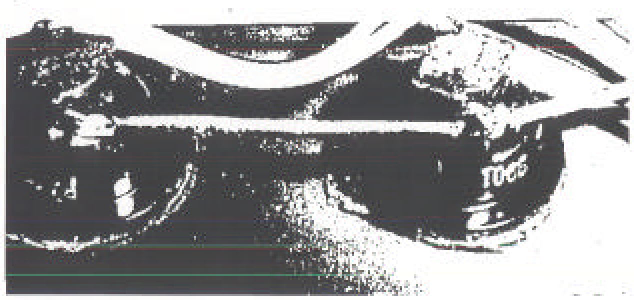
BATTERY DISCHARGE

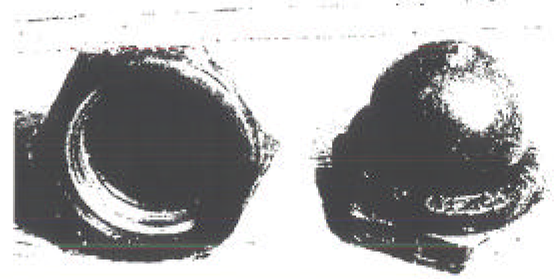


SALT-FOG









CONCLUSION

- PQT SETTERS
- DEMO RS-422 INTERFACE w/ PALLADIN
- IMPLEMENT MODS
- TYPE CLASSIFY AUG 2000
- AWARD CONTRACT FOR 3,500 SETTERS OCT 2000
- EPIAFS
- RS-422 POWER ON/OFF

STANAG 4560

Electro-Explosive Devices

Assessment and Test Methods for the Characterization

B. T. Lock

Secretary Electrical/Explosive Hazards Committee

Ordnance Board

Ordnance Safety Group

SCOPE

BACKGROUND

DOCUMENT FORMAT

EFI/EBW CHARACTERIZATION

CONCLUSION

BACKGROUND

The Dream

The conclusion drawn from the papers presented at a number of NDIA FUZE Conference which highlighted Exploding Foil Initiators (EFI)

WERE

MILITARY:

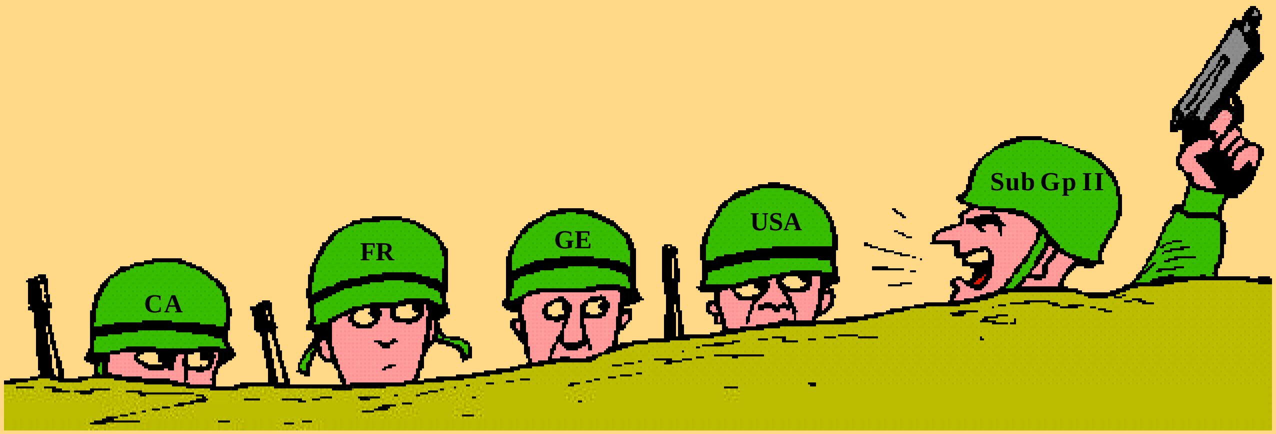
If they are that safe we want to see Explosive Foil Initiators (EFI) in service.

INDUSTRY

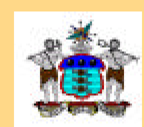
They are safe but what tests do the safety community require to justify this.

In 1996 AC 310 Sub Group 2

recognize that unless some one put their head above the parapet we would always be waiting.



So they formed a working group of national specialist to draft a STANAG on EFI



First Hurdle

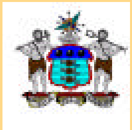
Q What NATO documentation covers the characterization of Electro-Explosive Devices (EED) ?

A None

STANAG 4560

Electro-Explosive Devices Assessment and Test Methods for the Characterization

DOCUMENT FORMAT



Format

Main Body Aim & Agreement

ANNEX A National Points of Contact

ANNEX B Characterization of EED

ANNEX C National Standards for the Assessment of EED

ANNEX D EBW and EFI Characterization

AIM of STANAG 4560

The aim of this agreement is to standardise the methodology and procedures by which EED are characterised, in order to assist in their assessment for safe and suitable use by NATO forces

PARTICIPATING NATIONS AGREE TO:

Characterize EED in accordance with the methodology and procedures set out in this STANAG.

Apply this STANAG to the development and acquisition of EED for use within military weapon systems developed after its promulgation.

Provide to the custodian of this STANAG, National Points of Contact (POC) for Safety and Suitability for Service (S3) assessments of EED.

The safety data developed in accordance with this STANAG shall be made available to other NATO nations , from the NSAAs or appropriate authorities as listed in Annex A.

TYPES OF EED

BRIDGEWIRE (BW)

FILM BRIDGE (FB)

CONDUCTING COMPOSITION (CC)

SEMICONDUCTOR BRIDGE (SCB)

EXPLODING BRIDGEWIRE (EBW)

EXPLODING FOIL INITIATOR (EFI)

ANNEX A

National Points of Contact

Typical Examples:

UK The Secretary of the Electrical/Explosive Hazards Committee
Ordnance Board
Ordnance Safety Group
Walnut 2c #67
MOD Abbey Wood,
Bristol
BS34 8JH

US **Army**

Chairman
US Army Fuze Safety Review Board
Attn: AMSTA-AR-FZ
Picatinny Arsenal, NJ 07806-5000

Chairman
Ignition System Safety Review Board
Attn: AMSAM-SF
Redstone Arsenal, AL 35898-5130

Navy

Chairman,
Weapon System Explosives Safety Review Board
Naval Ordnance Safety & Security,Code N71
Farragut Hall Building D323
23 Strauss Avenue
Indian Head, MD 20640-5555

Air Force

USAF, Non-Nuclear Munitions Safety Board
Attn: AFDTC/SES
1001 North 2nd Street, Suite 366
Eglin Air Force Base
FL 32542 - 6838

ANNEX B

Characterization of

Electro-Explosive Device

Ser No	Test	BW & FBW	CC	Devices SCB	EFI	EBW
(a)	(b)	(c)	(d)	(e)	(f)	
1	Visual Inspection	x	x	x	x	x
	<u>Electrical Tests</u>					
2	Firing Properties Test	x	x	x	x(1)	x(1)
3	Resistance	x	x	x	x	x
4	Malfunction Threshold			x	x(1)	x(1)
5	Thermal Time Constant	x	x	x	x	
6	Static Discharge (25kV)	x	x	x	x	x
7	Insulation Properties	x				
	Environmental Tests (2)					
8	Thermal Shock	x	x	x	x	x
9	Humidity	x	x	x	x	x
10	Leakage	x	x	x	x	x
11	1.5 m Drop	x	x	x	x	x
12	Electric Cook-off	x	x	x	x	
13	Vibration	x	x	x	x	x
14	Shock	x	x	x	x	x
	<u>Function Tests</u>					
15	Performance Tests	x	x	x	x(1,3)	x(1,3)
16	High Voltage				x(1)	

Notes: (1) Tests using actual system Fire-Set
(2) Dependent upon configuration
(3) Functioned at Hot, Cold and Ambient

Ser No	Test	Devices				
		BW & FBW	CC	SCB	EFI	EBW
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	Visual Inspection	X	X	X	X	X
	<u>Electrical Tests</u>					
2	Resistance	X	X	X	X	X
3	Firing Properties Test	X	X	X	X	X
4	Malfunction Threshold			X	X	X
5	Thermal Time Constant	X	X	X	X	
6	Static Discharge (25kV)	X	X	X	X	X
7	Insulation Properties	X				

Ser No	Test	BW & FBW	CC	Devices SCB	EFI	EBW
	Environmental Tests					
8	Thermal Shock	X	X	X	X	X
9	Humidity	X	X	X	X	X
10	Leakage	X	X	X	X	X
11	1.5 m Drop	X	X	X	X	X
12	Electric Cook-off	X	X	X	X	X
13	Vibration	X	X	X	X	X
14	Shock	X	X	X	X	X
15	Performance Test	X	X	X	X	X
16	High Voltage				X	

Second Hurdle

BW, FB, and CC devices have been characterised over the past 35 years using separate national test procedures

These procedures, though different, are normally considered adequate tests providing the NSAA, or other appropriate authority, to whom the test data should be provided, monitors them

ANNEX C

National Standards for the Assessment of EED

ANNEX C

List those Countries and their National documentation which presently cover the characterization of EED

France:

Measurements of the Characteristics of Explosive Components - Test Procedures G.T.P.S. No 12 May 1987

GAM DRAM 01

Germany:

TL 1375- 1100, Electro-explosive Devices - General Requirements.

VG 95 378 (Part 3) - EMC of Electro-Explosive Devices (EED) Fundamentals for Determining Characteristic Values.

ANNEX C

List those Countries and their National documents which presently have cover the characterization of EED

<u>UK</u>:

Pillar Proceeding P101 (2) Principles for the Design and Assessment of Electrical Circuits Incorporating Explosive Components.

Pillar Proceeding P112 (1) Electro-Explosive Devices Assessment and Characterization.

<u>USA</u>:

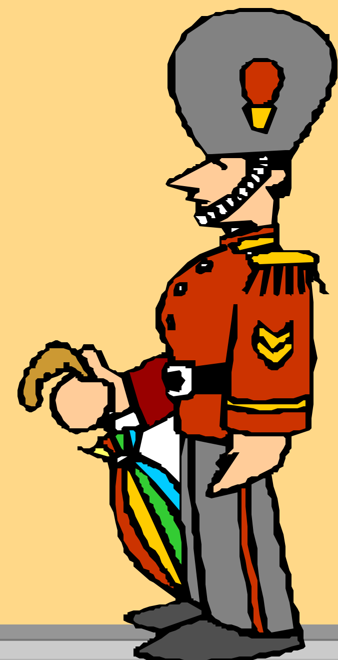
MIL- I-23659 Initiators, Electric, General Design Specification For.

MIL-STD-1512 Electro-explosive Subsystems, Electrically Initiated, Design Requirements and Test Methods.

MIL-STD-331 Fuze and Fuze Components, Environmental and Performance Tests for Testing.

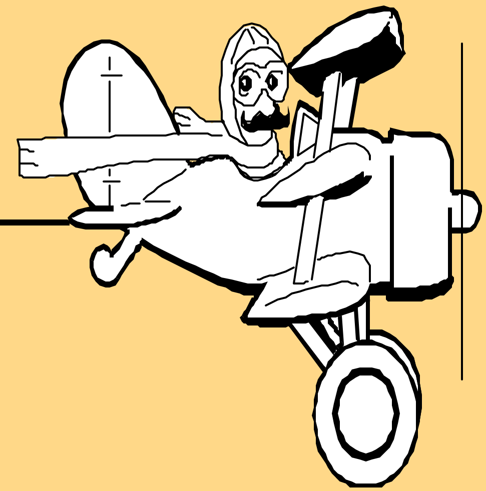
SEMICONDUCTOR BRIDGE (SCB)

Due to immaturity the method of characterisation is still under investigation and will be covered in the next edition.



ANNEX D

EBW and EFI Characterisation Tests



Ser No	TEST	Para	MINIMUM QUANTITIES									
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
			90	30(1)	22	40	10	6	50	50	50	5
1	Visual Inspection	4	x	x	x	x	x	x	x	x	x	x
2	Resistance	5	x	x	x	x	x	x	x	x	x	x
3	Firing Properties Test	6	x									
4	Malfunction Threshold	7		x								
5	Thermal Time Constant	8				x						
6	Static Discharge (25 kV)	9			x							
7	Thermal Shock	10							x	x	x	
8	Humidity	11					x					
9	Leakage	12					x					
10	1.5 m Drop	13							x	x	x	
11	Electric Cook-off	14						x				
12	Vibration	15							x	x	x	
13	Shock	16							x	x	x	
14	Performance Test (Amb)	17			x		x		x			
15	Performance Test (Hot)	17								x		
16	Performance Test (Cold)	17									x	
17	High Voltage	18										x

EBW and EFI Characterization Tests

Visual Inspection: Examination of all initiators shall be made according to the manufacturers inspection criteria.

Resistance: For initiators which do not contain a bridge gap the resistance shall be measured in accordance with MIL-STD 202 or national equivalent.

EBW and EFI Characterization Tests

Firing Properties Test

Determine the mean firing stimulus , standard deviation, minimum all-fire and maximum no-fire stimulus (voltage/energy)

Method of statistical Analysis: Test procedures shall be approved by National safety Approving Authority (NSAA). Typical methods Bruceton, Langley, Neyer, or Probit.

Fire Set: The firing unit shall use the same circuit components as those used in the tactical firing unit.

Firing Properties Test

Three temperatures

-54, 23 and 71^{0}C

No less than 30 initiators at each temperature

Definition:

No-fire Threshold (NFT). The level at which there is a 0.1% probability of fire at the 95% lower single sided confidence limit.

All-fire Threshold (AFT). The level at which there is a 99.9% probability of fire at the 95% single sided confidence limit.

EBW and EFI Characterization Tests

Malfunction Threshold (MFT)

Maximum No-damage Current (Statistical).

Maximum No-damage Current (Worst Case).

Bridge Opening Current.

Thermal Time Constant

The thermal time constant is the ratio of the electrical energy to the electrical power which causes that same type of damage to the EFI bridge as the MFT.

EBW and EFI Characterization Tests

Static Discharge 25 kV

Test Technique: Should be conducted in accordance with STANAG 4239 AOP 24

Number of Devices: >20

Where devices fail the test at 25 kV the NSAA may request additional testing to determine the maximum pass voltage level.

EBW and EFI Characterization Tests

Thermal Shock	To the requirements of STANAG 4370 AECTP 300 Method 304 or STANAG 4157 when used in a fuze
Humidity	To the requirements of STANAG 4370 AECTP 300 Method 306
Leakage	To the requirements of STANAG 4157 AOP 20 Test C8

EBW and EFI Characterization Tests

1.5 m Drop	To the requirements of STANAG 4370 AECTP 141, STANAG 4157 AOP 20 Test A4 or Def Stn 00-35 Test M5
Electric Cook-off	When required by the NSAA the initiator shall not exhibit a functional explosive reaction from exposure to 500 v.
Vibration	To the requirements of STANAG 4370 AECTP 400 Method 401 Procedure 3 (material installed in missiles)

EBW and EFI Characterization Tests

Shock	To the requirements of STANAG 4370 AECTP 400 Method 403
Performance Test	The initiator shall fire and produce the correct output when initiated with the minimum firing voltage for an intended application while temperature conditioned at -54, 23 and 71^{0} C
High Voltage	The initiator shall meet the functional requirements when initiated by a firing pulse at the limits of the capability of the firing system or 150% of the application specific design firing voltage, which ever is less

Acknowledgements

Sub Gp II National Specialist

Special Mention to:

Jeffrey Lienau USA

& manufacturers and engineers who may not have realised we do read their papers:

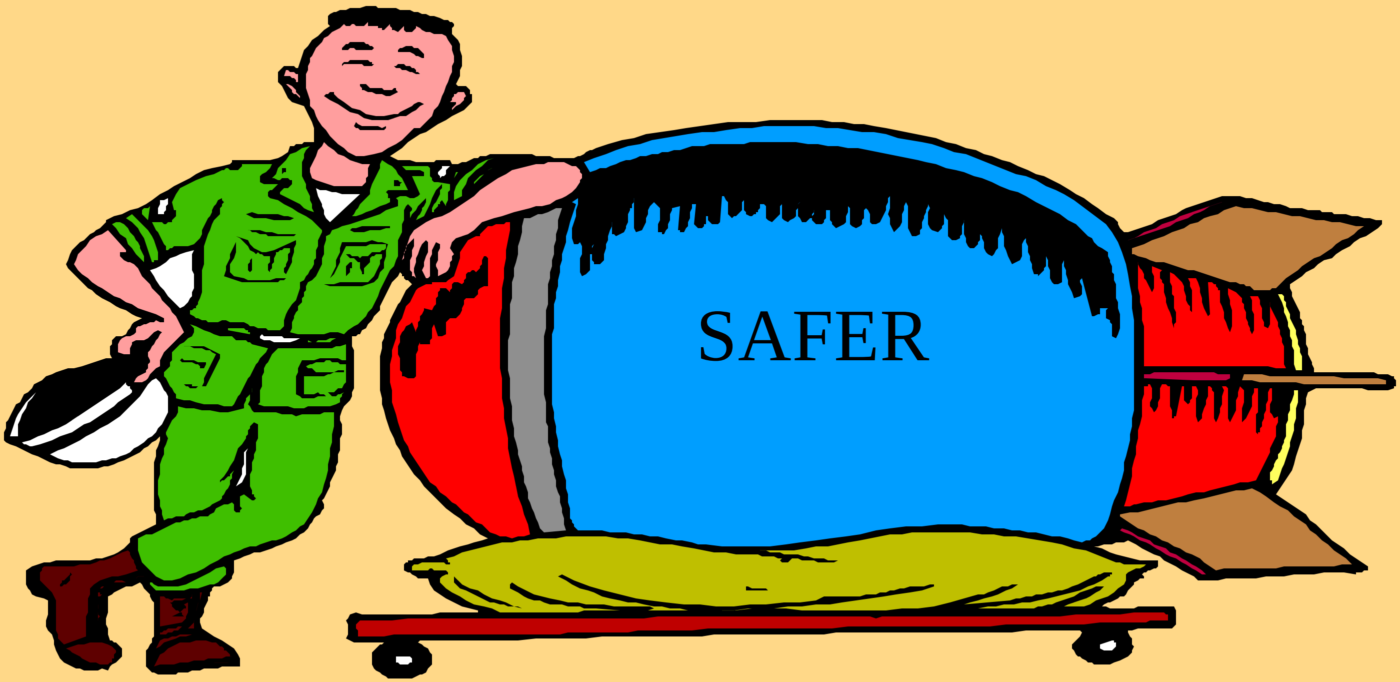
Barry Neyer - EG&G (now called PerkinElmer)

Lucient Nappert - DREV Canada

Steve Baker - EEV

Mike Tomlinson & Niel Hunt - Thomson Thorn Missiles

Lets hope that the inclusion of EFI provides us with



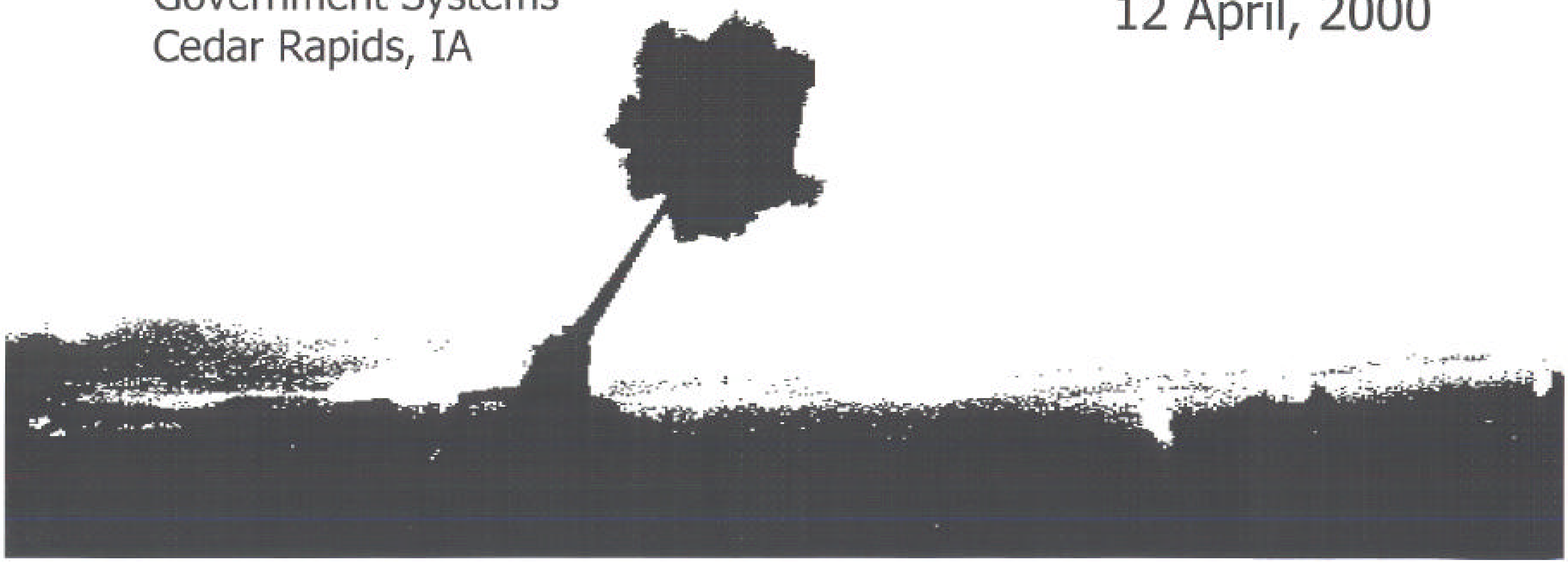
As well as more reliable weapon systems

Rockwell Collins' Artillery GPS Engine

Tom Mills

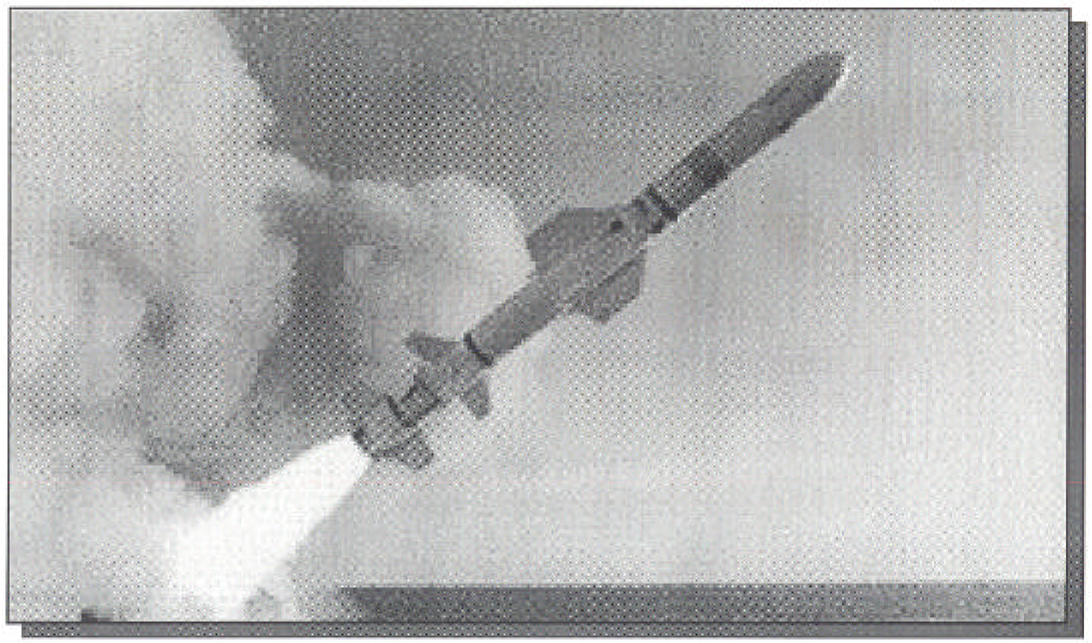
Rockwell Collins
Government Systems
Cedar Rapids, IA

44th Annual NDIA
Fuze Conference
12 April, 2000



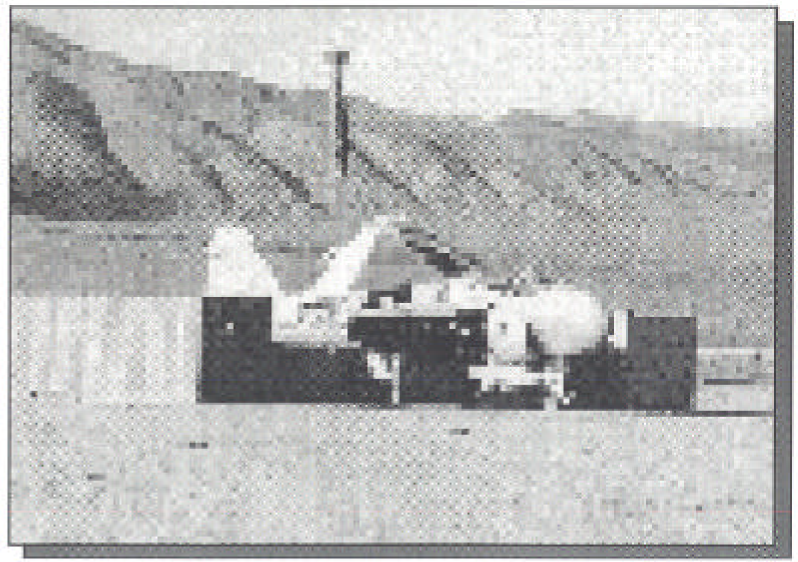
Munitions

- GPS has been on missiles since the mid-1980's



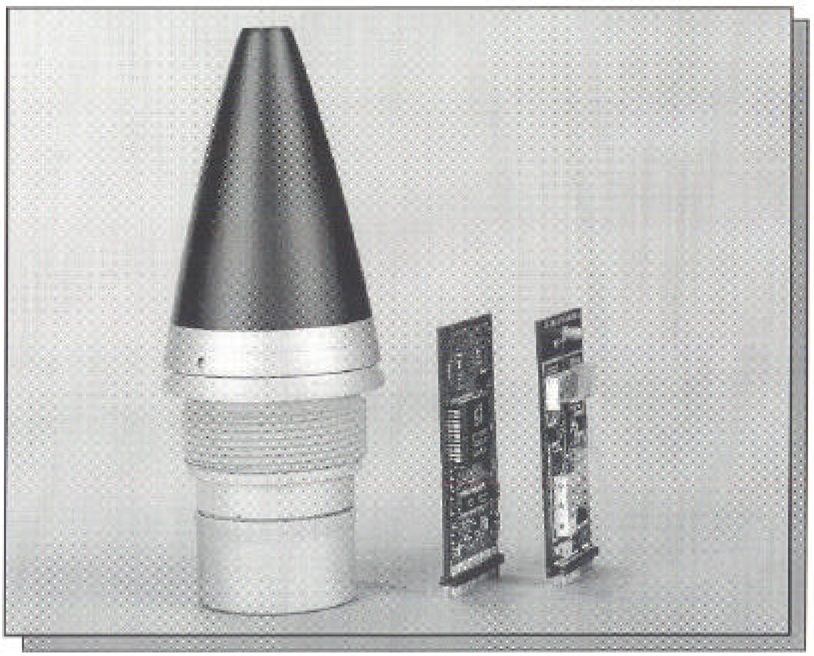
Inexpensive

- In the mid-1990's it became inexpensive enough to put on bombs

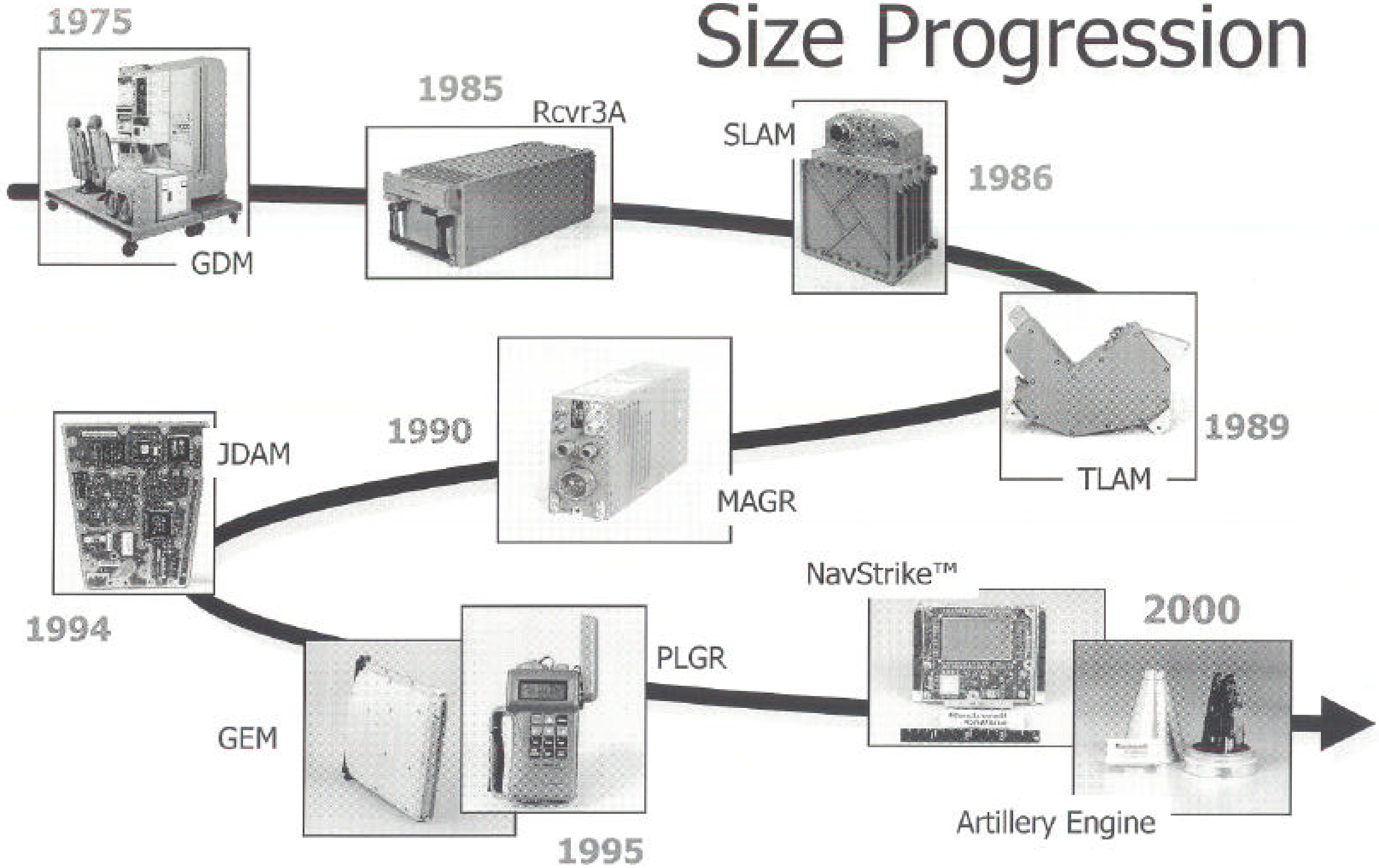


Smaller

- Now it has become even more inexpensive, and small enough to put into artillery



Size Progression



Variety of weapons

- Rockwell Collins provides GPS solutions for two basic classes of armaments:
  - Missiles, Rockets & Bombs
  - Artillery & Mortars

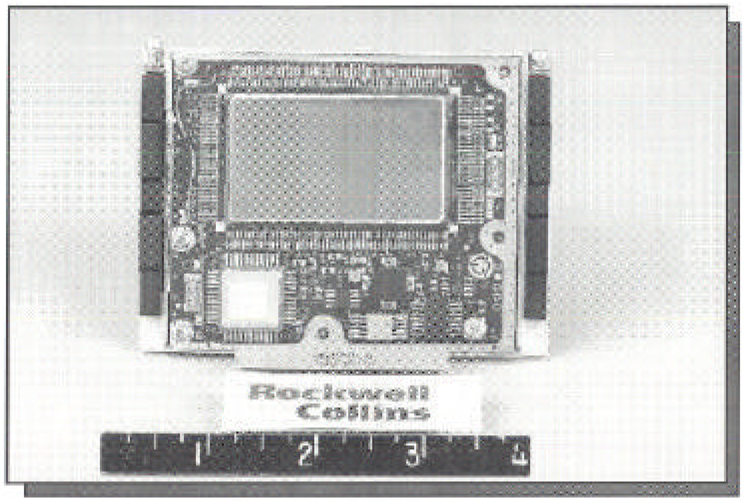
History with Missiles

- Rockwell Collins is the leading producer of GPS receivers for Missiles and Bombs:

ATACMS (Missile)	Tomahawk Block III
SLAM	Standard Missile 3
M270-A1 (Launcher)	SLAM-ER
AGM-130	JDAM (2000 lb. bomb)

- Previous GPS solutions were unique for each usage
- Today's 'Standard Product' for missiles is the **NavStrike**™

NavStrike™ Capabilities



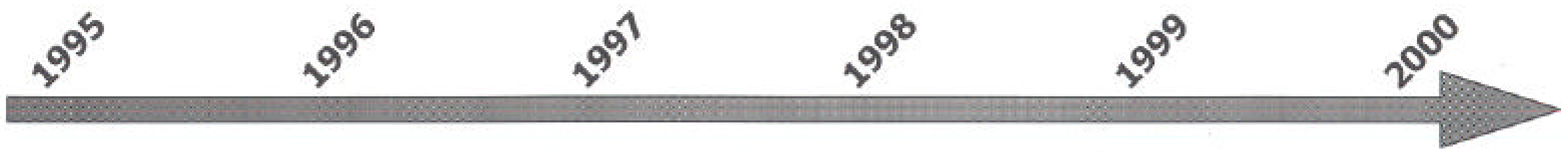
- 3.0" x 3.5" SAASM based GPS Receiver Design
- High Speed CMOS/422/232 Serial Interfaces
- Keying Via Host Control Serial Interface, DS-101 and DS-102

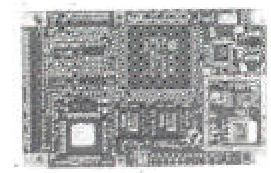
- 12-Channel All-in-View Receiver
  - Track & Navigation
- Fast Direct-Y Code Acquisition
- Dual Frequency L1/L2 tracking
- High A/J (self contained)
- Field Reprogrammable Software
- Black Key Capable
- Pseudorange/Deltarange & PVT output
- Stand Alone GPS or INS Aided Mode
- Designed for
  - High G Vibration and Shock
  - Extended Temperature Range
  - Low Power Consumption

Security Approval

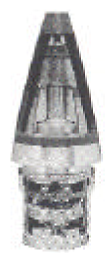
- BDRs (security reviews) held April 2000
- Approved by JPO (Joint Program Office)
- First Approved KDP II SAASM product
  - Common SAASM Module used in all future Rockwell Collins GPS products
  - NavStrike™ common GPS receiver for Precision Guided Munitions Applications

History with Artillery

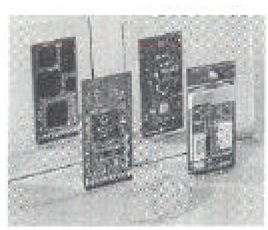




ERGM Demo
First GPS Acquisition on a gun fired, spin stabilized artillery shell



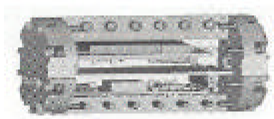
LCCM
Auto-registration fuze; GPS translator approach



CMATD
First Program to utilize the Acquisition Correlator Engine to perform Direct-Y code Acquisition

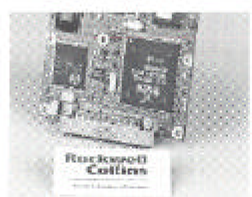
History with Artillery

1995 1996 1997 1998 1999 2000



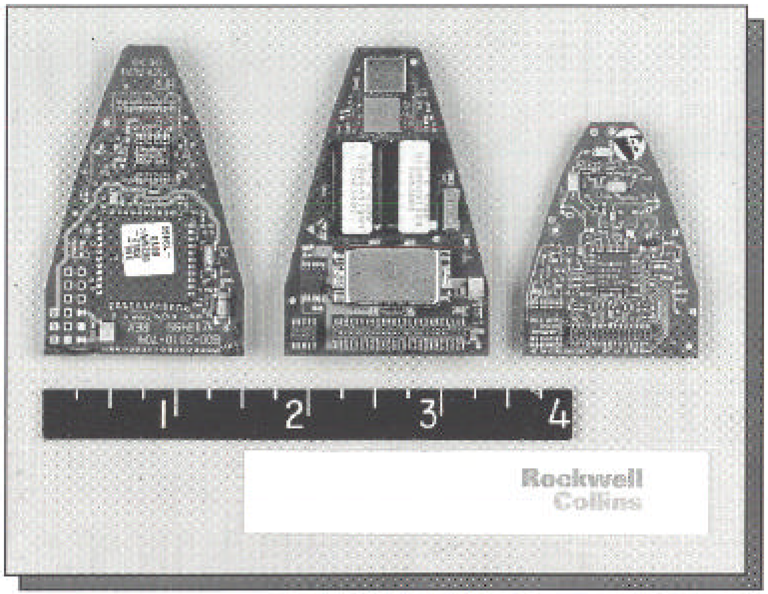
LCCCM/DERA
4 rounds fired at over16,000 G, successful Direct-Y acquisitions
1st Satellite acquisition in 3 sec, Nav solution in 6 sec

Team STAR
1D Corrector fuze; guidance and control in NATO std fuze volume



RIDGE
Artillery software modified for exo-atmospheric operation

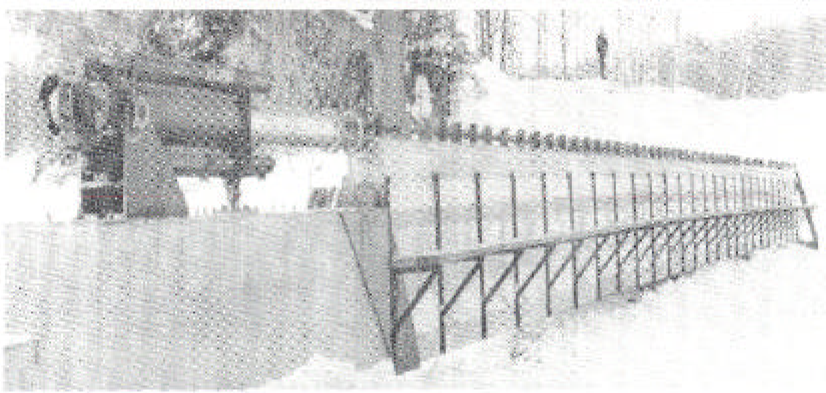
Artillery Engine Capabilities



- Miniaturized 3 Card Set
- 2.5 cubic inch volume
- High Speed CMOS/RS-232 Data and Initialization Interfaces
- KYK-13 Keying Interface

- 12 Channel All-in-View Receiver
- Fast Direct-Y Code Acquisition
- Ruggedized to over 16,000 g's
- Field Reprogrammable Software
- L1 RF input For Compact Size
- Trajectory & INS Aiding capable
- Embedded Navigation / Flight Correction software
- Integrated 2-chip DSP solution
- Low Power consumption, under 2 watts average
- Master receiver initialization (no track before launch)
- G-hardened GPS oscillator

Oscillator Testing



- G-hardened GPS Oscillator Development
  - + Over 200 Oscillators shock tested to over 16,000 g
  - + Designs from various suppliers evaluated
  - + Artillery oscillator selected, additional robustness enhancements in process
  - + 3 volt miniaturized version planned
  - + Excellent performance results achieved in live gun fire tests
  - + Design goal 2 ppm,
    Test results under 0.5 ppm

Summary

Rockwell Collins is the Guidance and Navigation provider for multiple types of munitions applications

Rockwell Collins has the GPS products available TODAY for all Missiles and Munitions Applications

BWB WFI 5

DaimlerChrysler Aerospace

TDW Gesellschaft für verteidigungs-
technische Wirksysteme mbH

NATIONAL DEFENSE INDUSTRIAL ASSOCIATION
STRENGTH THROUGH INDUSTRY & TECHNOLOGY

The 44th Annual Fuze Conference
&
Munitions Manufacturing &
Technology Symposium VII

„Flexibility In Fuzing"
&
„Technology Advancements
in Munitions Manufacturing"

April 10-12, 2000
Pleasanton, CA

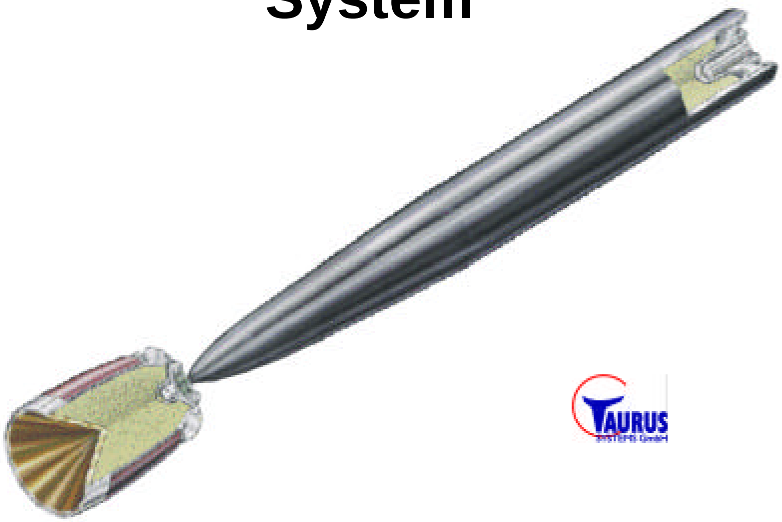
P I M P F

The

Intelligent Hard Target Fuze

for the

MEPHISTO Multiple Warhead System



TAURUS

Presented by:

- Dipl.-Phys. Friedrich Sauerländer*
  BWB - WF I 5, Germany

⇒ **German Air Force System Requirements**

- Dr. Helmut Muthig*
  TDW GmbH, Germany

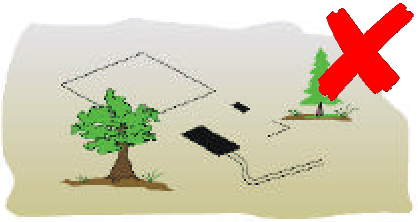
⇒ **Solution: Intelligent Hard Target Fuze**
P I M P F

- Dipl.-Ing. Andre Feustel
  TDW GmbH, Germany

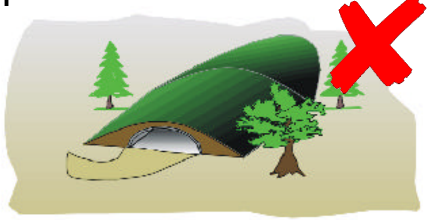
- Dipl.-Ing. Helmut Hederer
  TDW GmbH, Germany

Target Spectrum

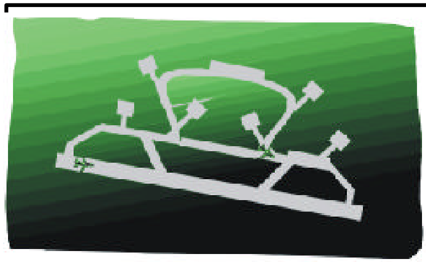
Point Targets | **Area Targets**



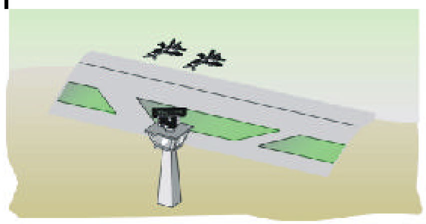
Bunker: direct/ indirect signature



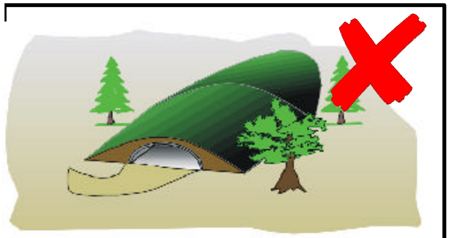
Shelter



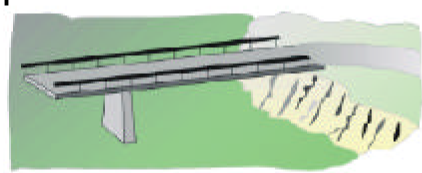
Taxiway & Runway



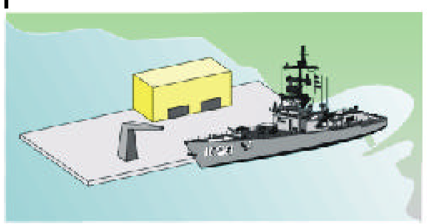
A/C in the Open



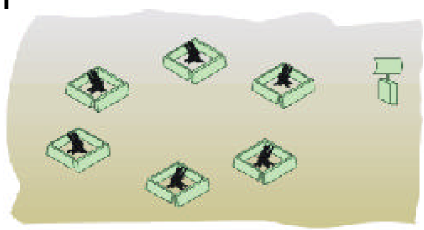
Ammunition Storage



Bridge Pier



Ships in Port



Fixed SAM-Sites

GAF System Requirements I

Carrier A/C:
- Tornado IDS
- Eurofighter 2000

Max. Weight: <1400 kg (3090 lb)

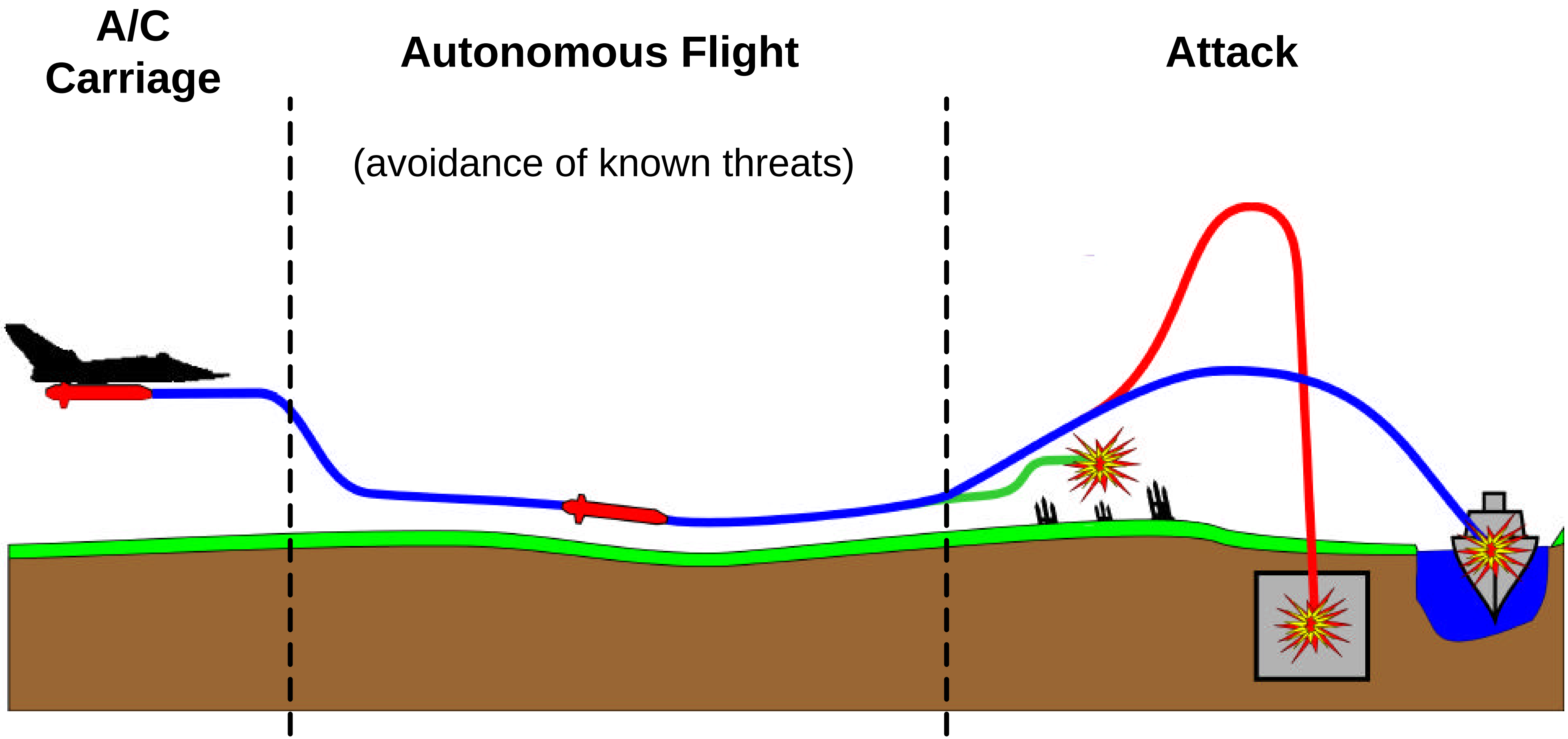
Max. Payload: <500 kg (1100 lb)

Max. Dimensions: ~500 cm x 100 cm x 70 cm
(L x W x H) (~197“ x 39“ x 28“)

Autonomous Flight: ~350 km (220 miles)

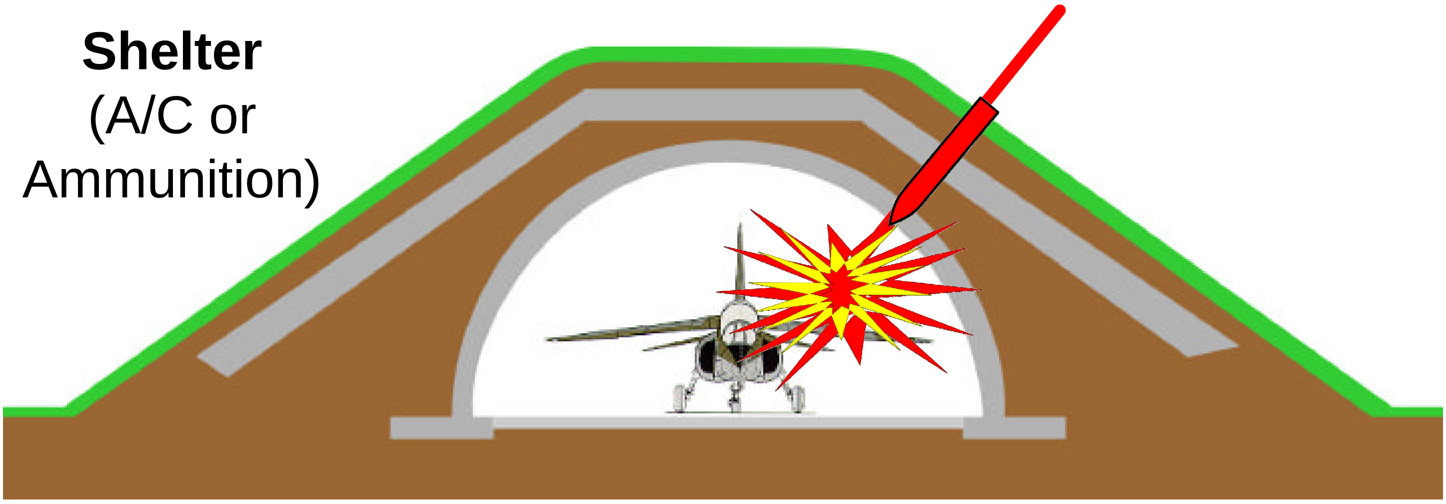
Adaptation possible to:
- Viggen
- JAS 39 Gripen
- F-16
- F-18
- F-111
- Harrier

Target Optimized Flight Profiles

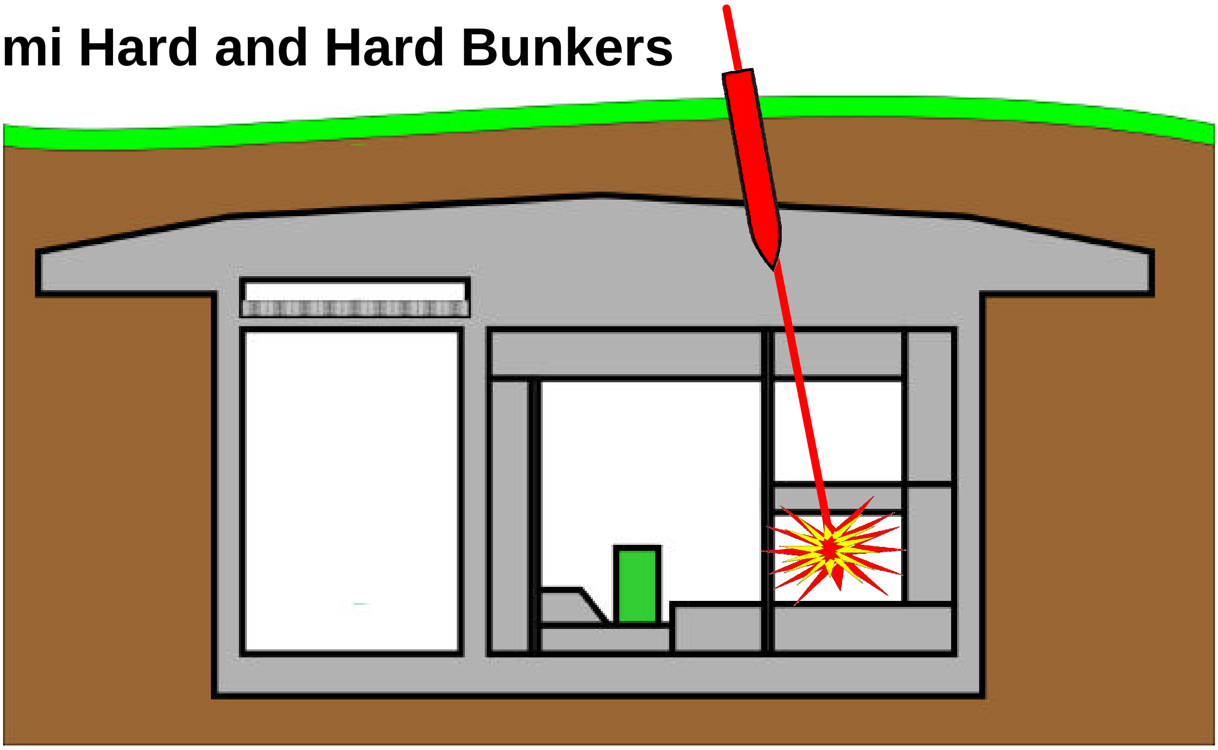


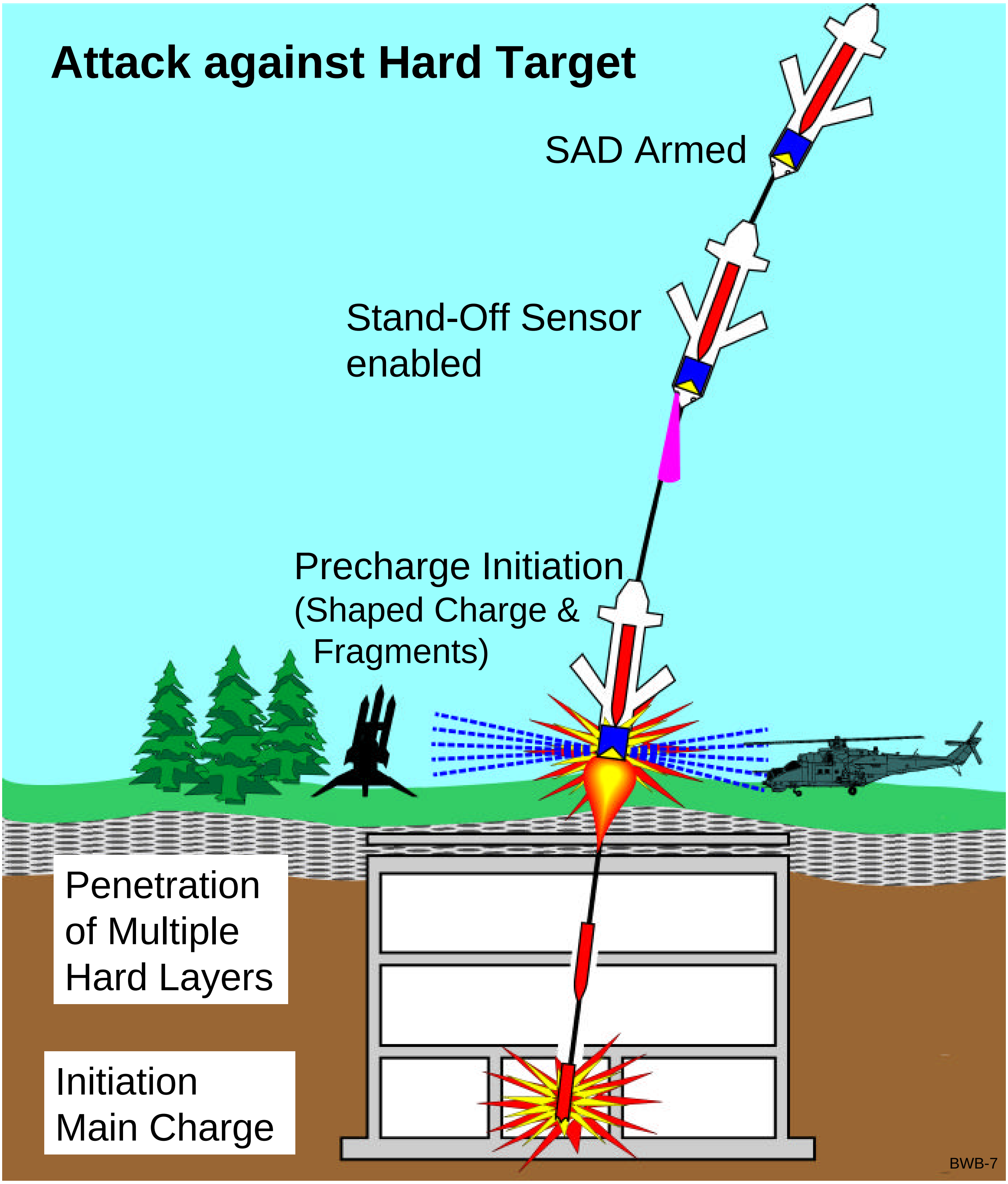
Typical Hard Targets

Shelter
(A/C or Ammunition)



Semi Hard and Hard Bunkers

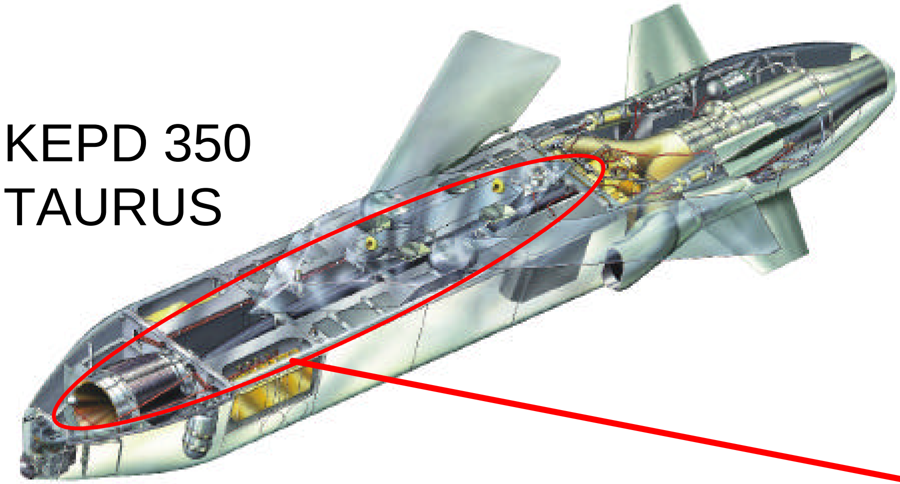



Attack against Hard Target
SAD Armed
Stand-Off Sensor enabled
Precharge Initiation (Shaped Charge & Fragments)
Penetration of Multiple Hard Layers
Initiation Main Charge
BWB-7

Solution

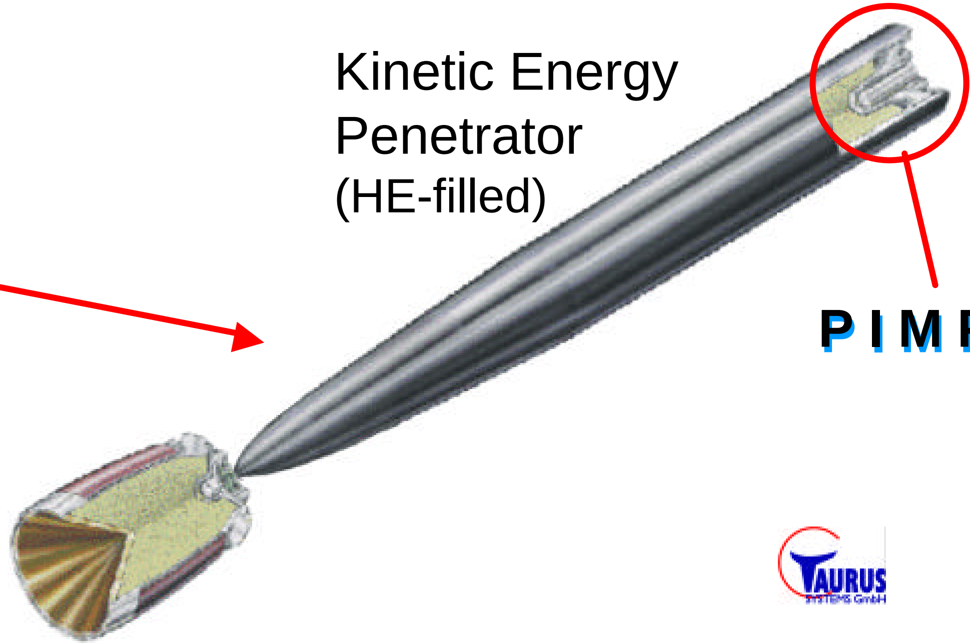
Missile

KEPD 350
TAURUS



Lethal Package

Kinetic Energy
Penetrator
(HE-filled)



P I M P F

Precharge
(Shaped Charge & Fragments)

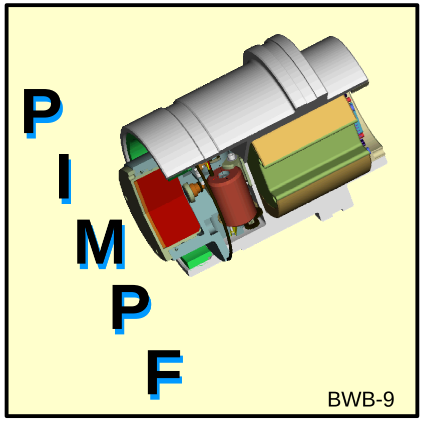
GAF System Requirements II

(Hard Targets)

~~List of Specific Hard Targets~~

Overall Performance Requirement

- Penetration of Typical Hard Bunkers
  - high strength reinforced concrete
  - single or multiple layers
  - below soil/gravel
  - for several attack angles
- **Target Optimized Fuzing**



P rogrammable
I ntelligent
M ulti-
P urpose
F uze

PIMPF **= Intelligent Hard Target Fuze**

for the ***MEPHISTO*** Penetrating **Multiple Warhead System (MWS)**

of the German ***TAURUS*** Stand-Off Weapon

Key Features of PIMPF

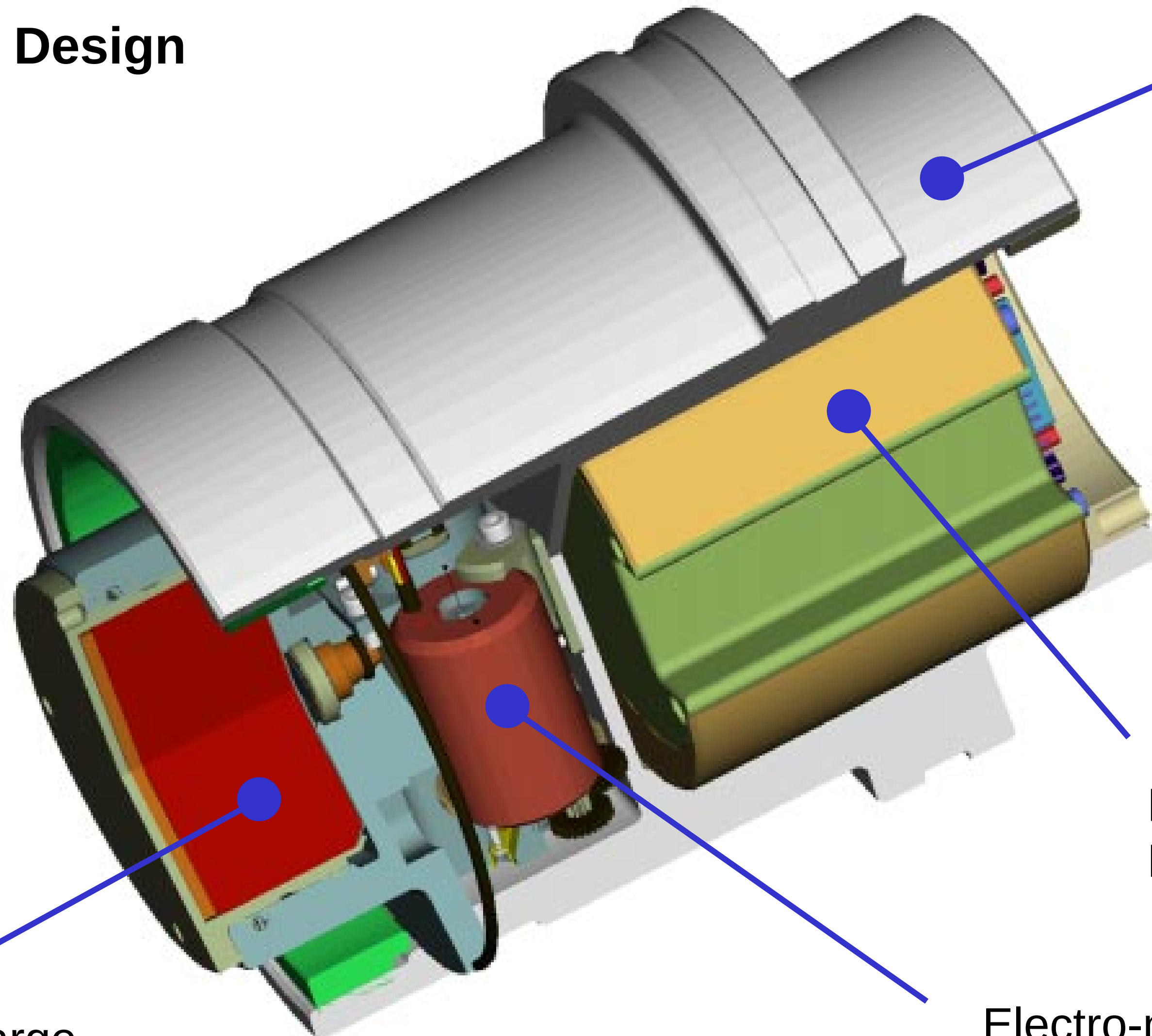
- *Shock sensing* and *intelligent signal processing*
- Detection of *hard and soft layers* within layered hard target structures
  - ⇒ ***event detection and layer counting capability***
- ***Void detection***
- Pre-programmable selection of target types
- Optimum fuzing point according to target structure
- Built-In-Test capability
- High g-load resistance

PIMPF is <u>not</u> a simple <u>time delay</u> fuze -

it converts target features adaptively into precise fuzing <u>events</u> ,

it offers full <u>void detection</u> and <u>layer counting</u> capabilities

PIMPF Overall Design



PIMPF Subsystems

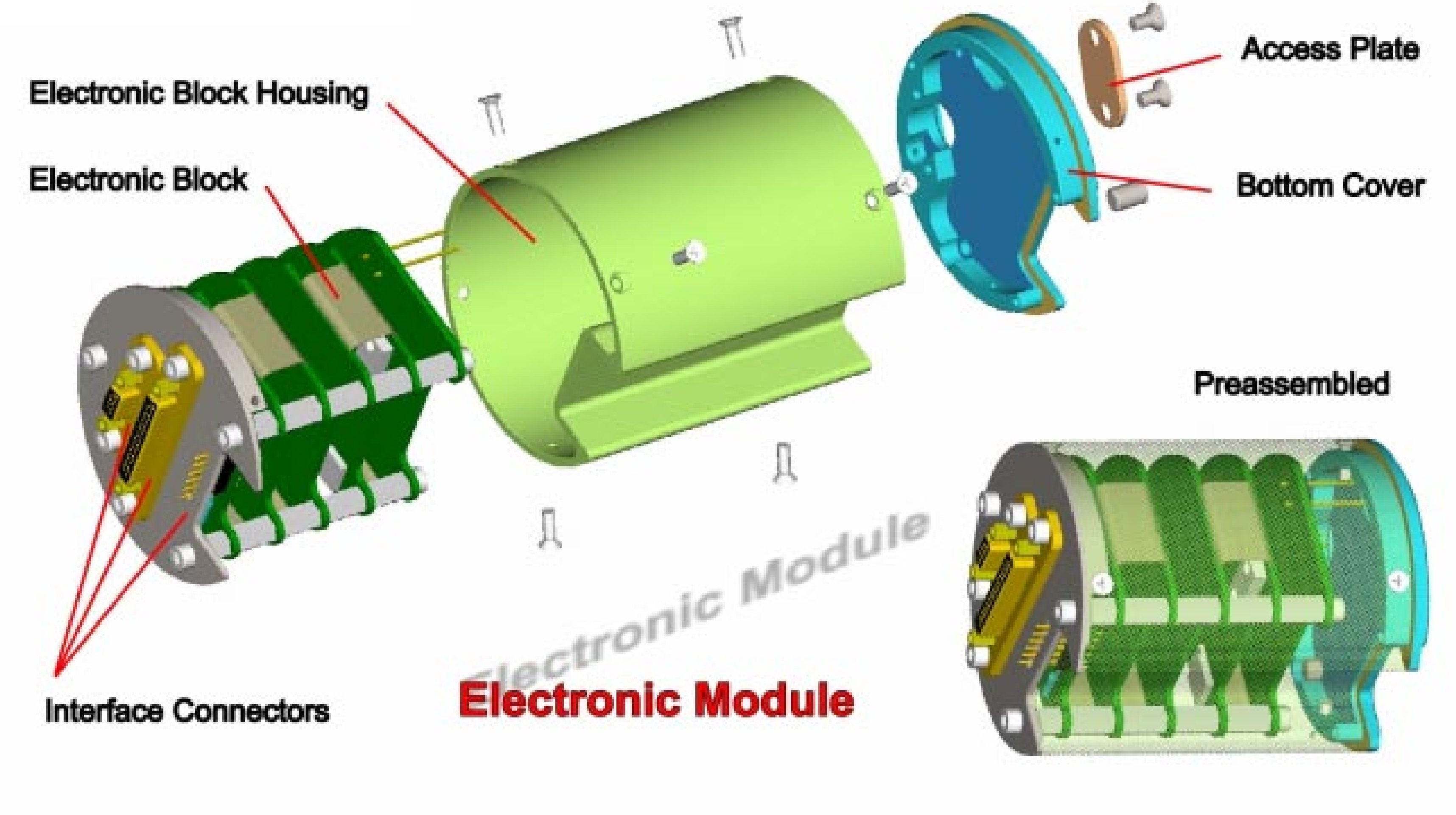
- Mechanical ***Safe & Arm Device*** according to STANAG 4187 including an ***Explosive Train*** with qualified elements

- ***Fuze Electronics Module*** with
  - **shock sensor**
  - µP-based **signal processing unit**
  - **RS 422 serial interface**

Modular design of PIMPF provides flexibility to support other W/H Systems

PIMPF Electronics Hardware

DIEHL Ammunition



PIMPF Fuze Electronics

PIMPF Verification Testing Carrier

Half Scale
MEPHISTO Penetrator Hardware
(Cal. 120 mm)

Sabot Design for Cal. 210 mm
M 110SF Howitzer

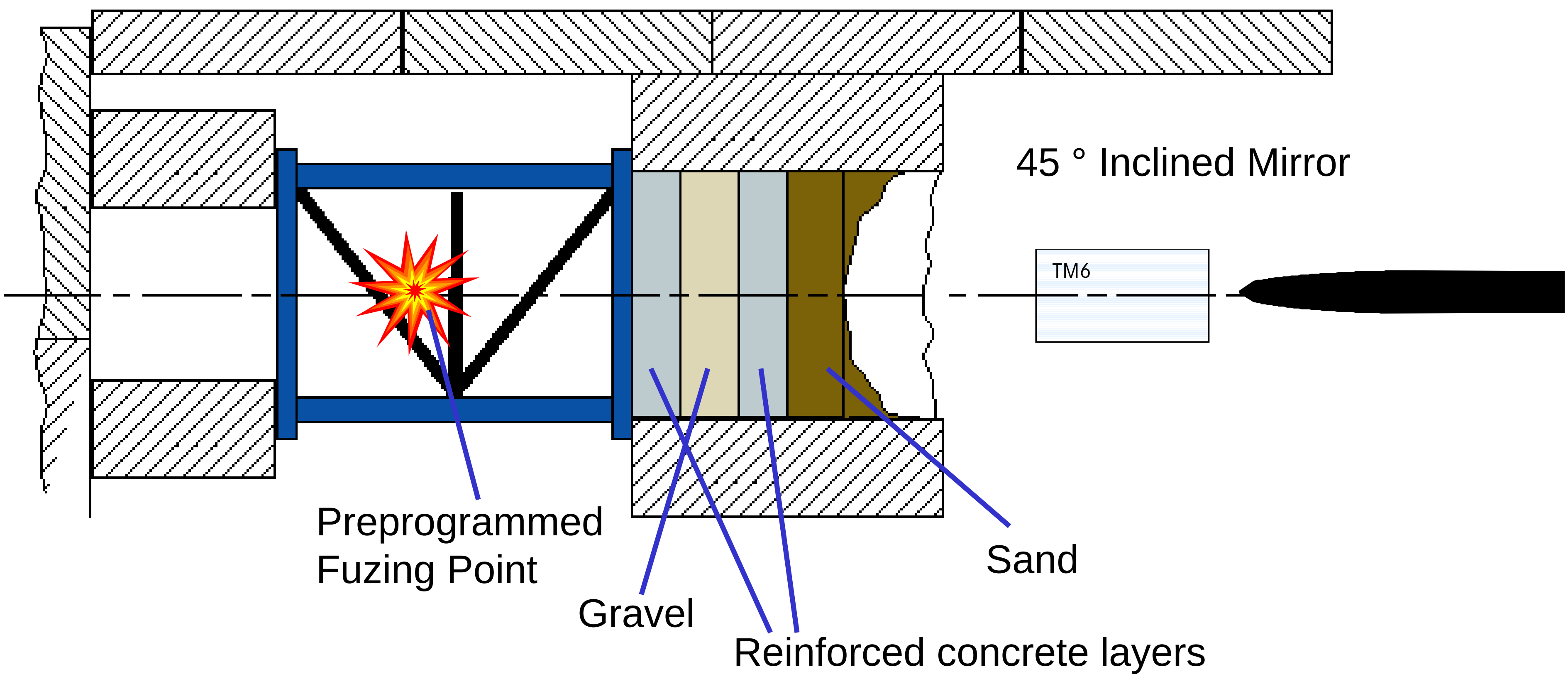
Test Site:
Meppen Proving Ground

Howitzer M 110SF
(Cal. 210)

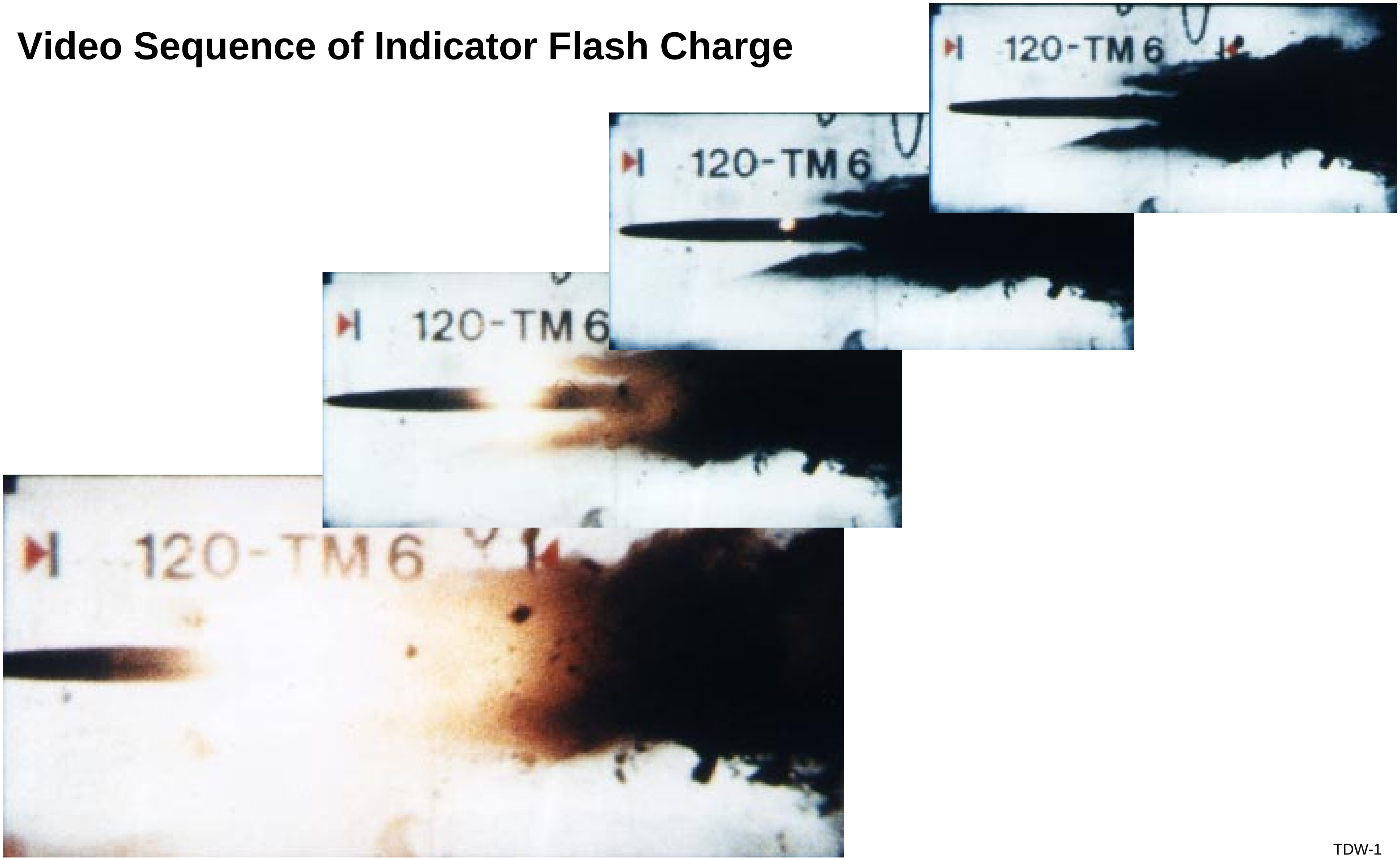
Hard Target Arena

Verification Target TM 6

(Layered *sand / concrete / gravel / concrete* target)



Video Sequence of Indicator Flash Charge

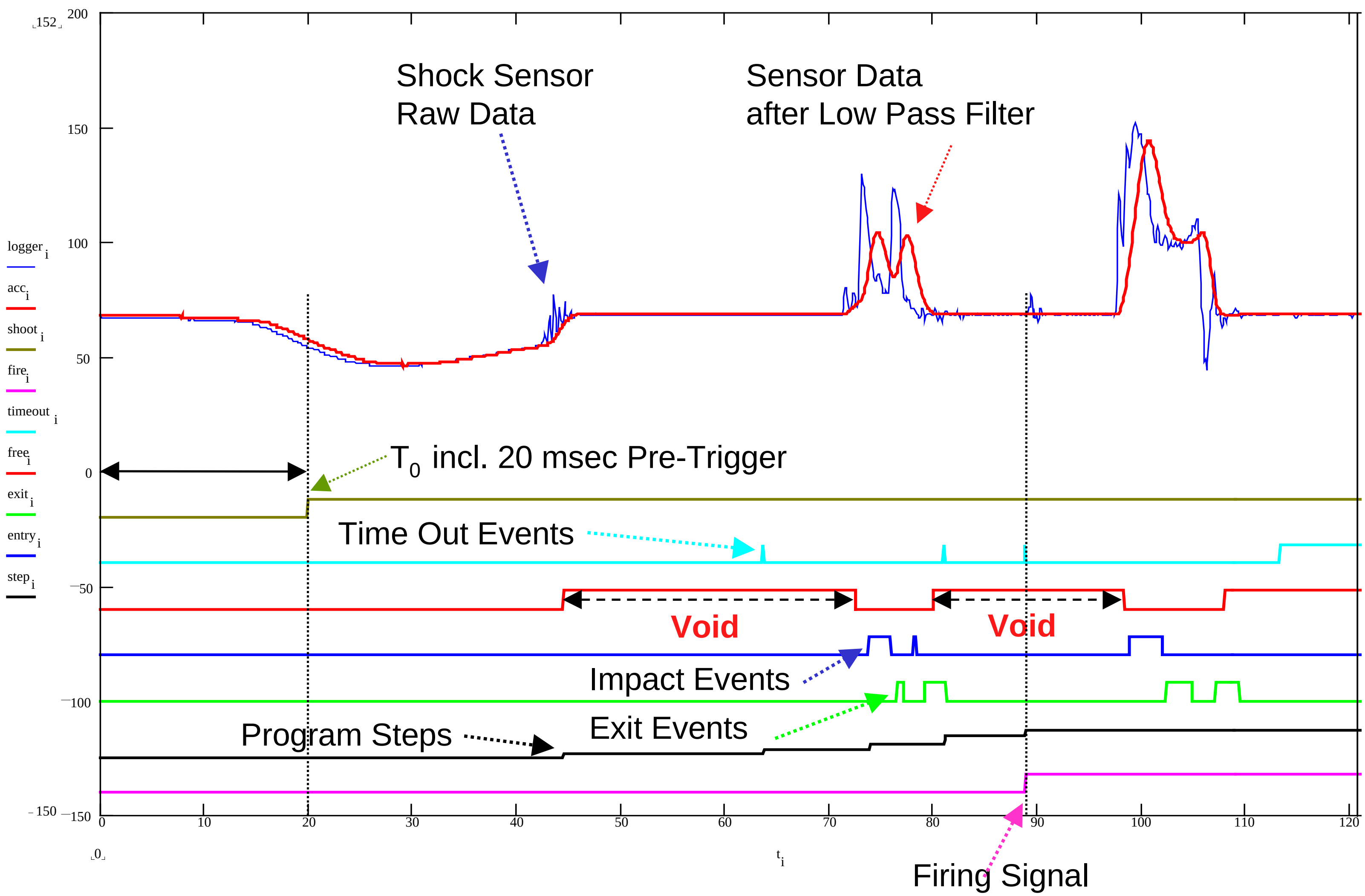


Test Results (1): Carrier Hardware

Penetrator stopped in
Getter Structure

Penetrator incl. PIMPF after Test

Test Results (2): Typical Recorded Events



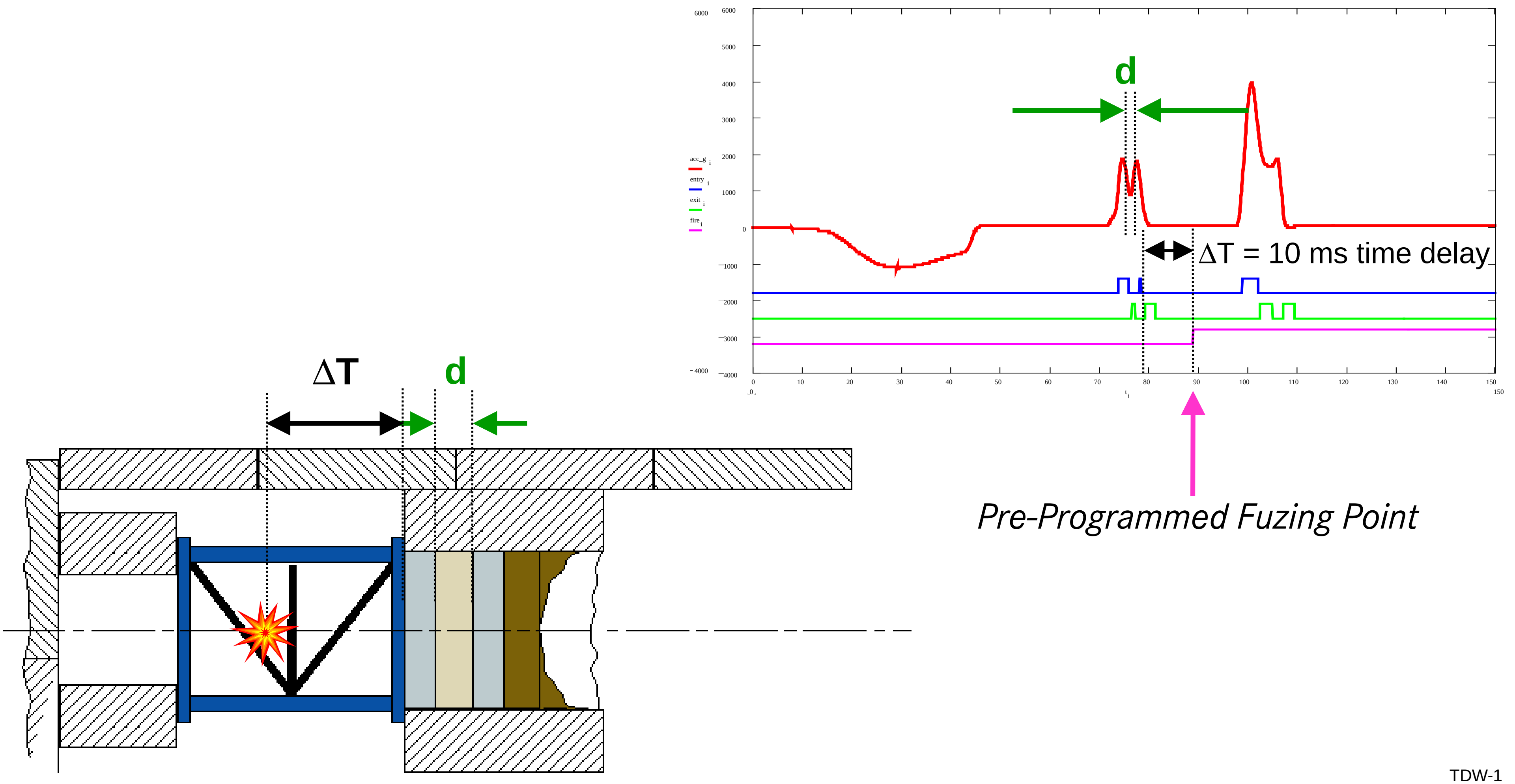
Intelligent Hard Target Fuze

DaimlerChrysler Aerospace

TDW Gesellschaft für verteidigungs-
technische Wirksysteme mbH

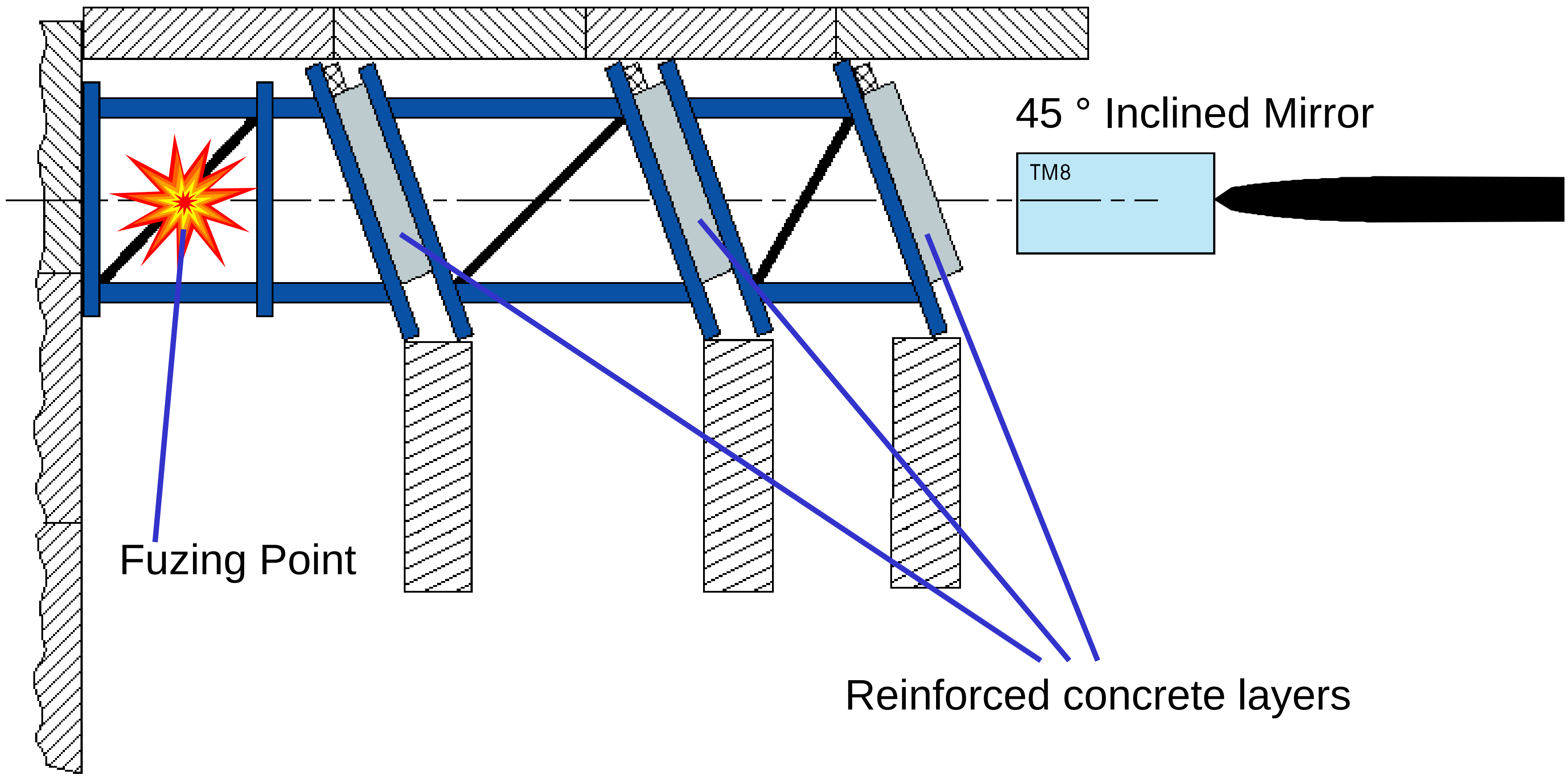
Verification Target TM 6

(Layered *sand / concrete / gravel / concrete* target)

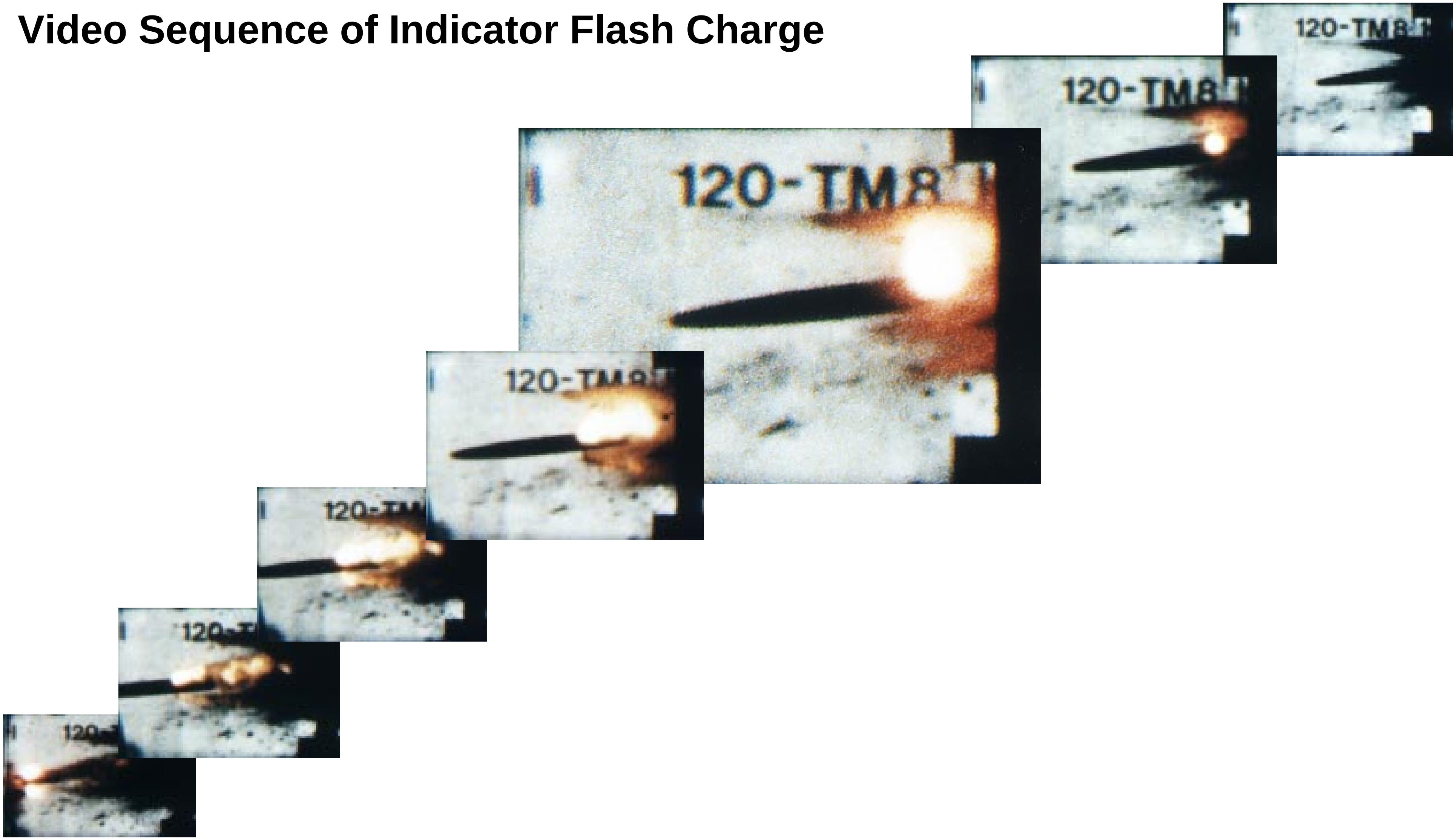


Verification Target TM 8

(3 inclined and spaced concrete layers)

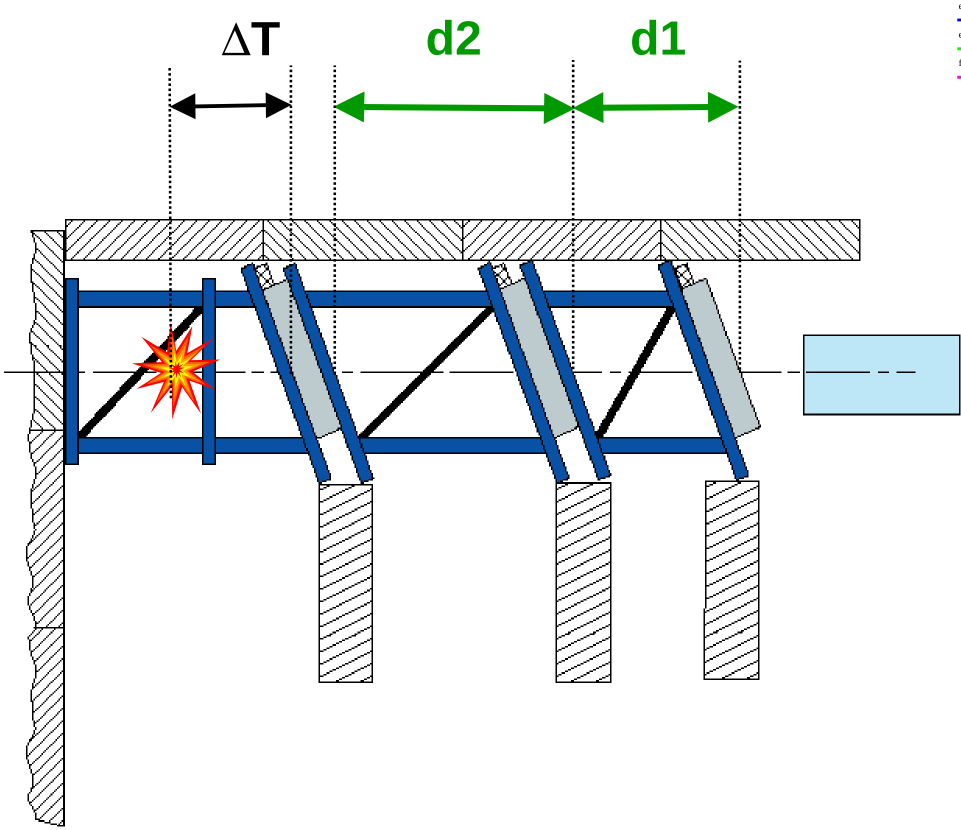


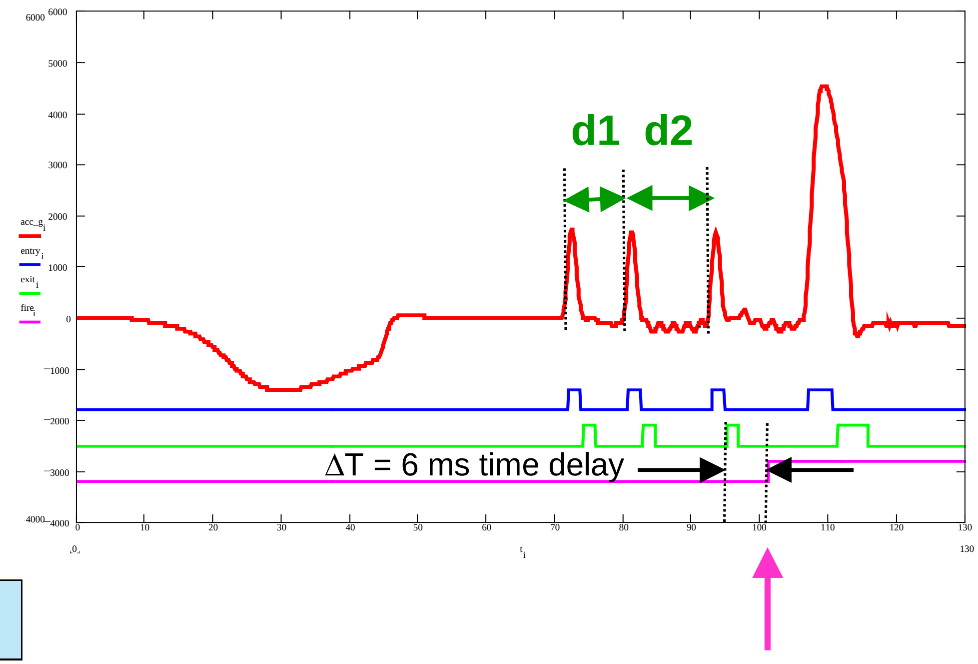
Video Sequence of Indicator Flash Charge



Verification Target TM 8

(3 inclined and spaced concrete layers)

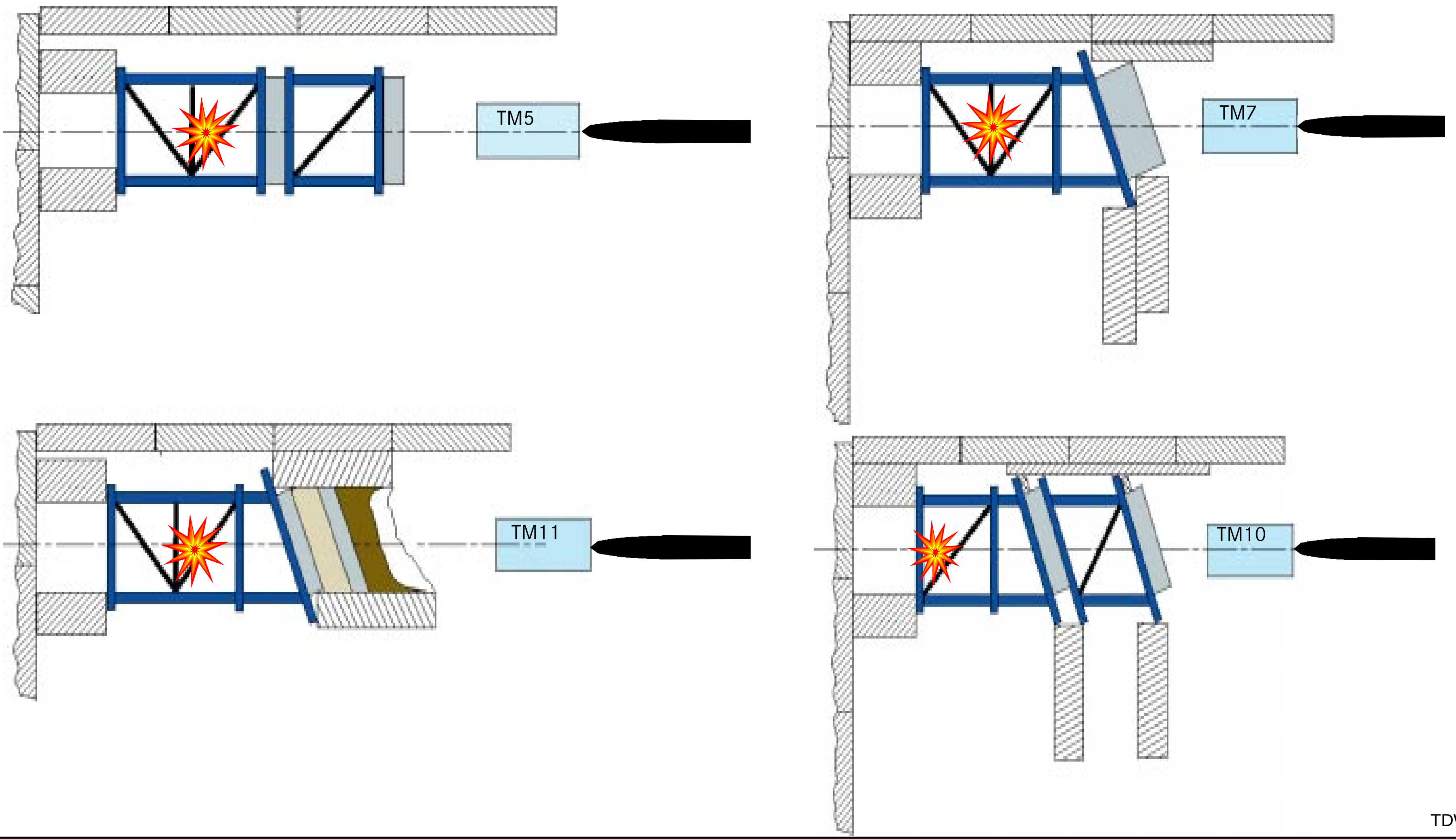




Pre-Programmed Fuzing Point

Selection of other Successful Verification Tests

(in total: 12 half scale tests)



SUMMARY

Key accomplishments

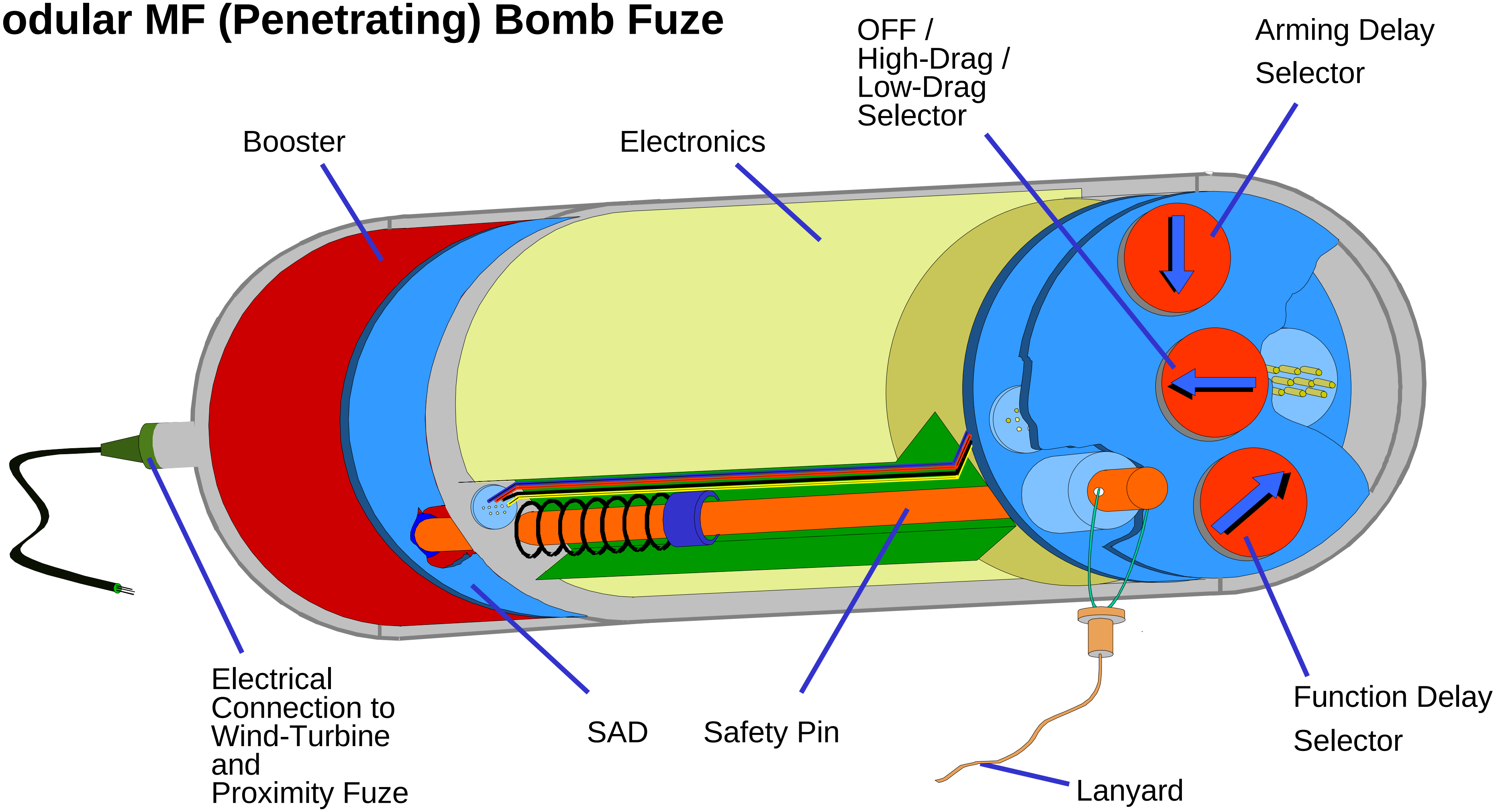
- ***Hardware*** survives high g-loads
- ***Intelligent Hard Target Algorithm*** is verified, fuzing point determination works
- ***Layer Counting*** and ***Void Detection*** capability is demonstrated

Schedule

• Development:	finalized 06 / 2000
• Qualification:	finalized 12 / 2000
• Production start:	2002, according KEPD 350 production plan

PIMPF system design and performance have been successfully demonstrated,
PIMPF is ready for qualification and industrialisation.

PIMPF Growth Potential:
Modular MF (Penetrating) Bomb Fuze

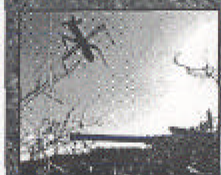


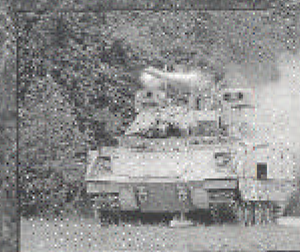
44th ANNUAL FUZE CONFERENCE

11-12 APRIL 2000

PEO TACTICAL MISSILES

PARTNERING FOR FUZE TECHNOLOGY INSERTION





COL CRAIG NAUDAIN
DIRECTOR,
SYSTEM INTEGRATION & OPERATIONS

PEO TACTICAL MISSILES PROGRAMS ORGANIZATION

PEO TACTICAL MISSILES

DEPUTY PEO
PRINCIPAL STAFF
EUROPEAN REP

AVIATION

PM AIR TO GROUND

LONGBOW HELLFIRE ACAT IC
LASER HELLFIRE
MODERNIZED HELLFIRE
APKWS

PM HYDRA 70

2.75" ROCKET SYSTEMS - ACAT II
CARGO WARHEADS
UNITARY WARHEADS
MOD 5 MK 66
DIGITAL FUZE

FIRE SUPPORT

PM ATACMS - BAT

ATACMS / BAT ACAT ID
BAT
BAT P3I
BLK II
ATACMS / APAM ACAT IC
BLK I
BLK IA

PM MLRS

M270A1 ACAT1C
IFCS ACAT III
ILMS ACAT III
ER-MLRS ACAT III
GMLRS ACAT III
HIMARS ACAT II
RRPR

MANEUVER

PM CCAWS

LOSAT ACTD
IBAS ACAT II
TOW ITAS
T2SS

PM JAVELIN

JAVELIN ACAT IC

FUZE00.ppt

PROGRAM EXECUTIVE OFFICER TACTICAL MISSILES

MISSION

Provide the American soldier with the finest, combat effective, tactical missile systems in the world in a timely and cost-effective manner.

Army Center of Excellence
For
Tactical Missiles

Guidance & Control Systems
Propulsion
Warheads
Seekers

VISION

A world-class government / industry team that gives the American soldier an unparalleled, overmatch tactical missile capability that allows our Army to fight and win the next conflict with minimal casualties in the shortest time possible.

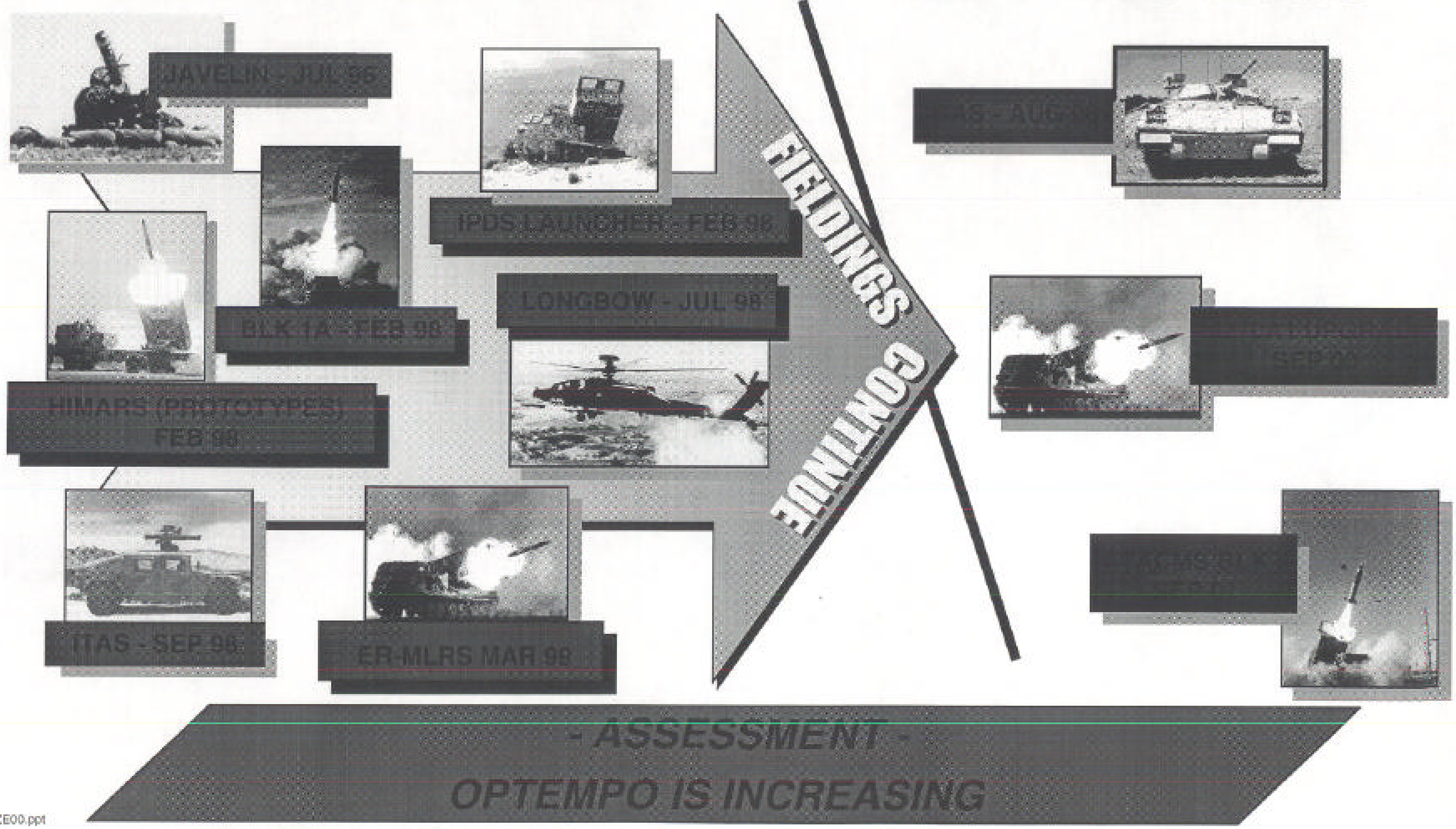
GOALS

- Excel beyond all others in fielding the best tactical missile systems in the world.
- Effectively team with industry.
- Build the Army Acquisition Corps of the future.
- Mature and weaponize critical technologies for the Army After Next. First Digitized Division / First Digitized Corps.
- Reduce the Life Cycle Cost of our missile systems by 20% during the period FY98-FY00.

FIELDING TO THE FORCE

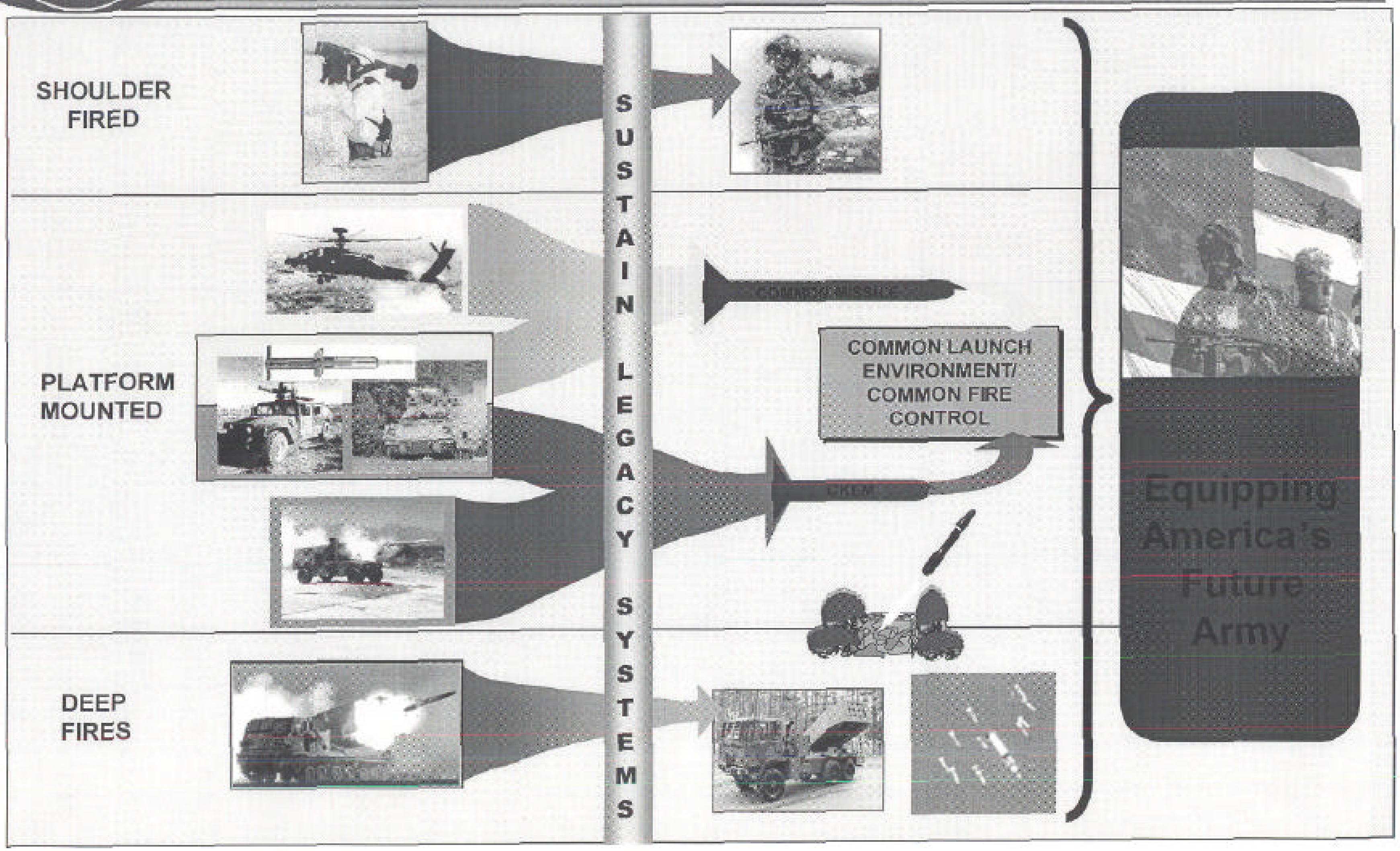
FUE: LAST THREE YEARS

NEXT TWO YEARS



FUZE00.ppt

PATH TO THE FUTURE



TACTICAL MISSILE OVERVIEW

KEY PLAYER IN ARMY TRANSFORMATION

Brigade Combat Team

- LOSAT Accelerated - Objective System for AT Company
- HIMARS Accelerated - Organic Battery
- JAVELIN Increased - Division's worth in a Brigade

Reduced Logistics Footprint

- GMLRS
- Common Missile

Common Calibre

- Common Missile
- Hydra 70/APKWS
- MLRS/ATACMS

Strategic Deployability

- HIMARS
- LOSAT

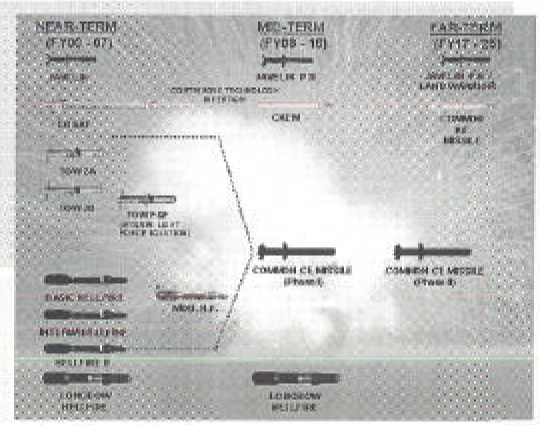
ARMOR THREAT HAS CHANGED...BUT SO HAS OUR MISSILE MODERNIZATION STRATEGY

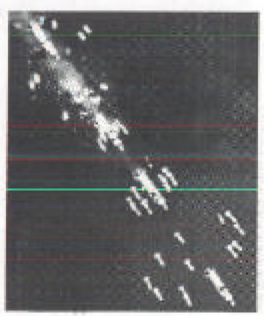
THREAT

- Fewer New Tanks - More Upgrades
- Defensive Aid Suites/Active Protection Systems
- Tanks viewed as Center of Gravity of Enemy Ground Forces - e.g. Kosovo

SOLDIER/PLATFORM STRATEGY

- Introduce Kinetic Energy Missile (LOSAT)
- Grow Javelin/Integrate with Land Warrior
- Migrate to Common Missile
  - Phased Requirements/Acquisition Strategy
  - Longer Production Run
  - Reduced Quantities = 35% of Tow + Hellfire buy



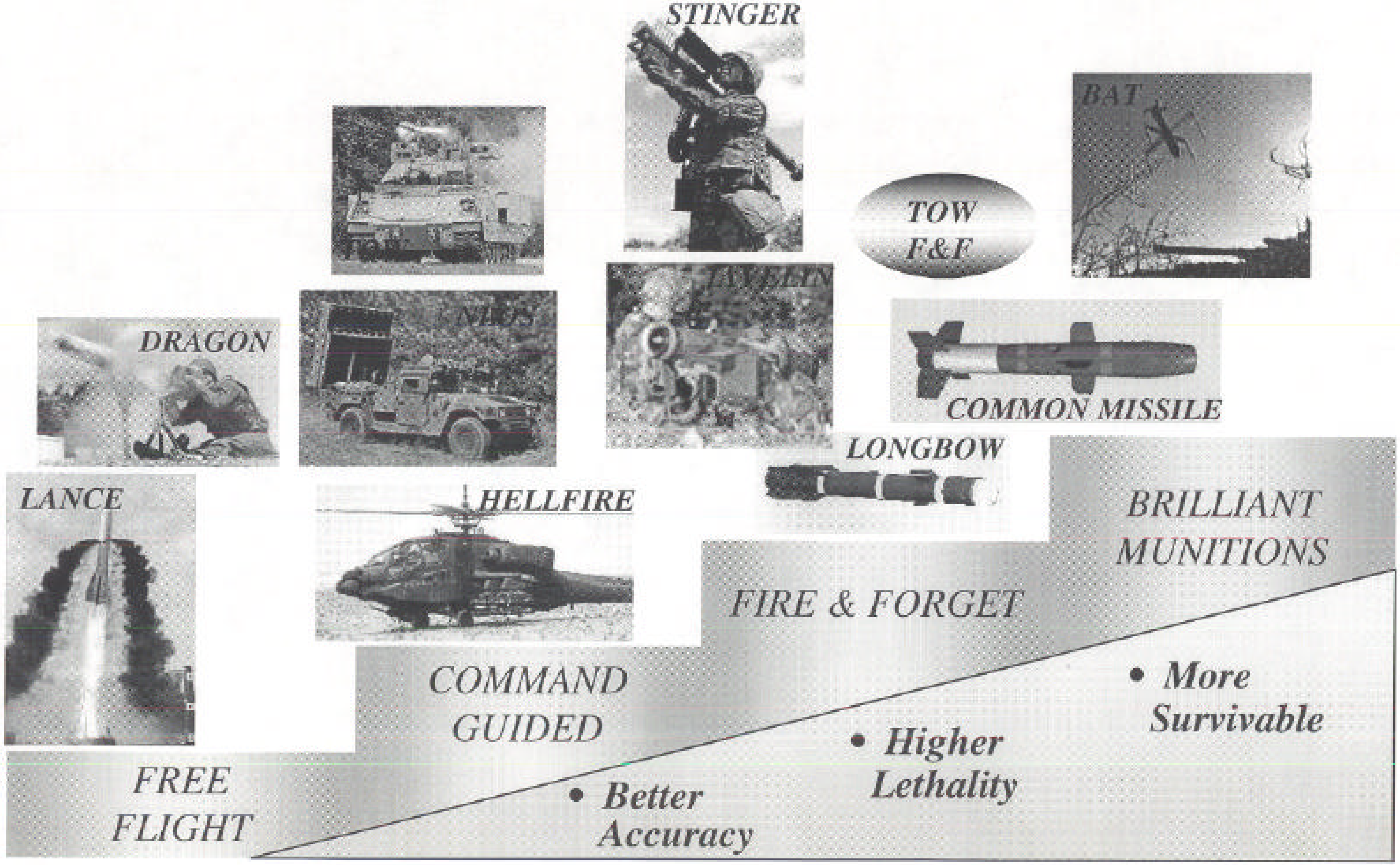


FIRE SUPPORT STRATEGY

- M270A1 - Digitized + Improved Survivability
- HIMARS - Strategic Deployability
- Precision Engagement - GMLRS, ATACMS, Unitary Warheads
- Shape the Battlespace - Block II engagements at long range

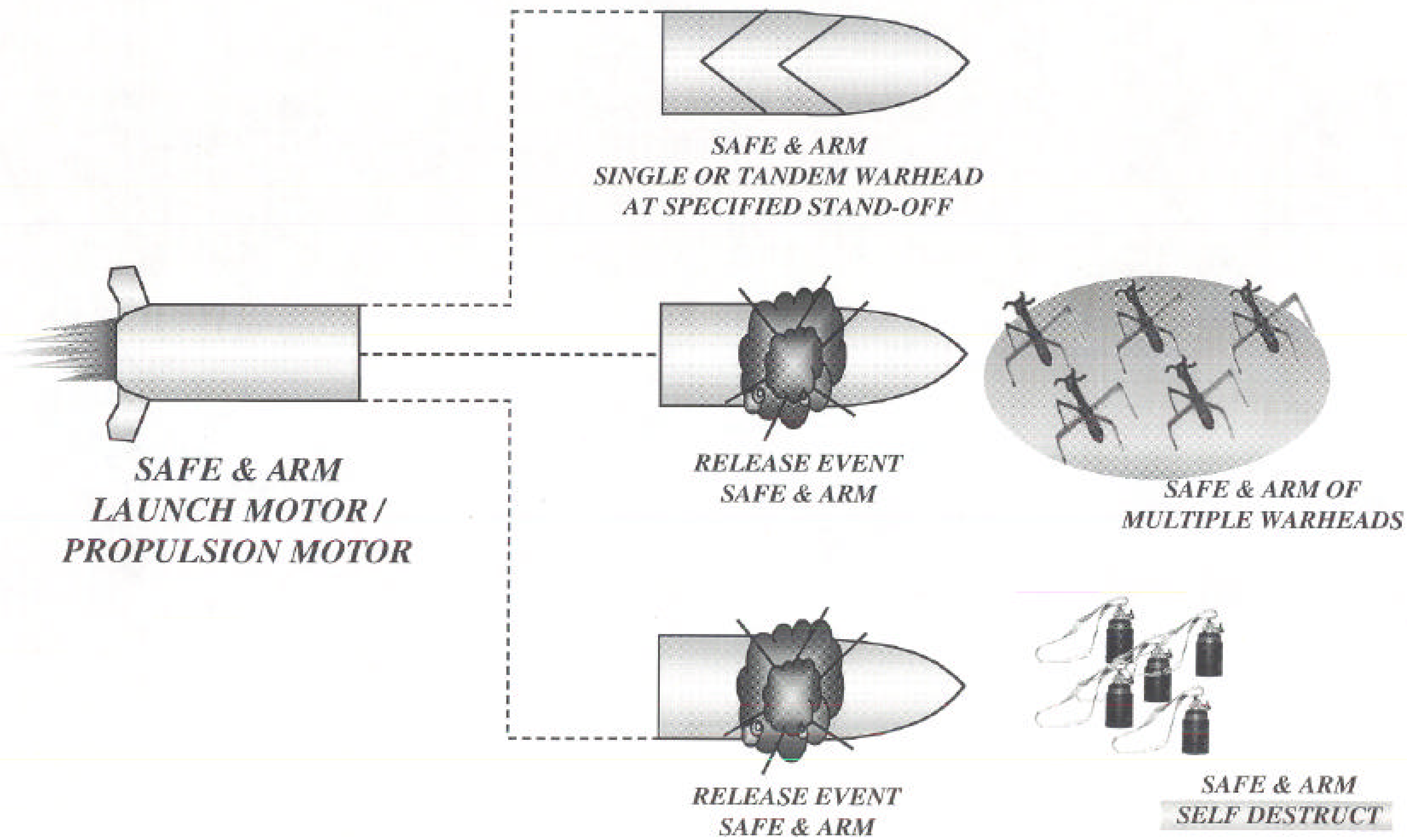
A TACTICAL MISSILE SNAPSHOT

MISSILE TECHNOLOGY TIMELINE



FUZE00.ppt

TACTICAL MISSILE FUZE FUNCTIONS



CURRENT FUZE TRENDS

- TECHNOLOGY - FROM MECHANICAL TO ELECTRONIC SAFE AND FIRE (ESAF)
- UNIQUE DESIGN FOR EACH WEAPON SYSTEM
- COSTLY
  - DEVELOPMENT COSTS FOR BAT, HELLFIRE, & JAVELIN
  - PROPOSED $13 MILLION
  - ACTUAL $42 MILLION
  - AVERAGE UNIT COST $3,500
- CHALLENGES

GENERAL LESSONS LEARNED IN FUZE DEVELOPMENT

- INVOLVE ARMY FUZE BOARD EARLY & FREQUENTLY
- CONTROL ARCING
- ONLY USE CERTIFIED SOURCES AND COMPONENTS
- VENDOR BASE IS SHRINKING
- COST OVERRUNS AND PERFORMANCE PROBLEMS SEEM TO BE A WAY OF LIFE
- STRIVE FOR COMMON REQUIREMENTS AND HARDWARE
- DISTRIBUTED SYSTEMS DIFFICULT TO ANALYZE AND CERTIFY VS STANDALONE ESAD

COST BENEFITS NOT ACHIEVED.
MATURE TECHNOLOGY NEEDED.

TACTICAL MISSILES

SELF-DESTRUCT FUZE

- REQUIREMENT
  - AFTER DESERT STORM AN OPERATIONS REQUIREMENT DOCUMENT (ORD) WAS ESTABLISHED REQUIRING FUZE OPERATION WITH <1% HAZARDOUS DUD RATE TO MANEUVER FORCES.
- FUNCTION
  - IF STAB DETONATOR IS NOT INITIATED UPON IMPACT, THE FIRING CAPACITOR, FOLLOWING A 3 MINUTE DELAY FUNCTIONS THE ELECTRICAL EXPLOSIVE DEVICE (EED)
  - IN THE EVENT THE FUZE FAILS TO ARM, THE DELAY CIRCUIT INITIATES THE EED WHICH DETONATES THE STAB DETONATOR AND STERILIZES THE GRENADE.
- CONCERNS
  - AGING OF COMPONENTS (RELIABILITY)
  - REPEATABILITY IN PRODUCTION
  - HIGH RATE EQUIPMENT
  - STABILITY OF VENDOR BASE

SDF LESSONS LEARNED

- VALIDATE THE COMPLETE DESIGN BEFORE PROCEEDING WITH HIGH RATE EQUIPMENT DESIGN AND FABRICATION
- UNDERSTAND THE COMPLEXITY OF A DESIGN AND THE IMPLICATIONS ON PRODUCTION BEFORE COMMITTING TO COST AND SCHEDULE
- HIGH RISK PROGRAMS SHOULD IDENTIFY AND RESOURCE LOW RISK ALTERNATIVES
- DEVELOP AND MAINTAIN OPEN LINES OF COMMUNICATION (TRUST, STABILITY, REALISTIC EXPECTATIONS)

WHY PARTNERSHIPS?

- WITH TRANSITION TO PERFORMANCE SPECIFICATIONS PARTNERSHIPS MUST BE FORMED IN ORDER TO ASSIGN RESPONSIBILITY FOR FUZE DESIGN AND TO ASSURE THE FOLLOWING OBJECTIVES ARE ACHIEVED:
  - LOWER COST
  - LOWER RISK
  - BUILD FROM DEMONSTRATED PERFORMANCE
  - CONTINUE O&S COST REDUCTIONS
  - DESIGN FOR TECHNOLOGY INSERTION

WILL PARTNERSHIPS WORK?

COMMON ELECTRONIC SAFE AND ARM FUZE (CESAF)

- REQUIREMENTS ANALYZED
- SYSTEM INSERTION POINTS IDENTIFIED
- TEST PLAN ESTABLISHED

RESULTS

- COMPETITION REDUCED UNIT PRICE ≈ 30%
- SET STAGE FOR COMMON MSL AND CKEM

CONCLUSION

PARTNERSHIPS ARE CRITICAL TO ASSURE FUTURE TACTICAL MISSILE SYSTEMS HAVE COMMON FUZE DESIGNS. WE SIMPLY CANNOT AFFORD TO DEVELOP AND SUPPORT NEW AND UNIQUE DESIGNS FOR EACH NEW WEAPON SYSTEM.

<u>BOTTOM LINE</u>: INDIVIDUALLY WE DO NOT HAVE ALL THE ANSWERS.

Injection Loading of Aluminized PBX

Kirk Newman and Neal Cowan

NSWCIHD, Code 930

Outline

- Introduction
- Submunition Design
- Formulation Considerations
- Process Design
- Process Control
- Benefit
- Conclusion

Introduction

- Navy has unique mission
  - Littoral Warfare *"from the sea"*
  - Using *"smart weapons"* from longer range
- Surface Strike issues
  - weapon expense limits number of rounds
  - submunitions provide better coverage (pH)
  - need greater individual lethality than DPICM

NAVSEA INDIAN HEAD Surface Warfare Center Division

Submunition Design

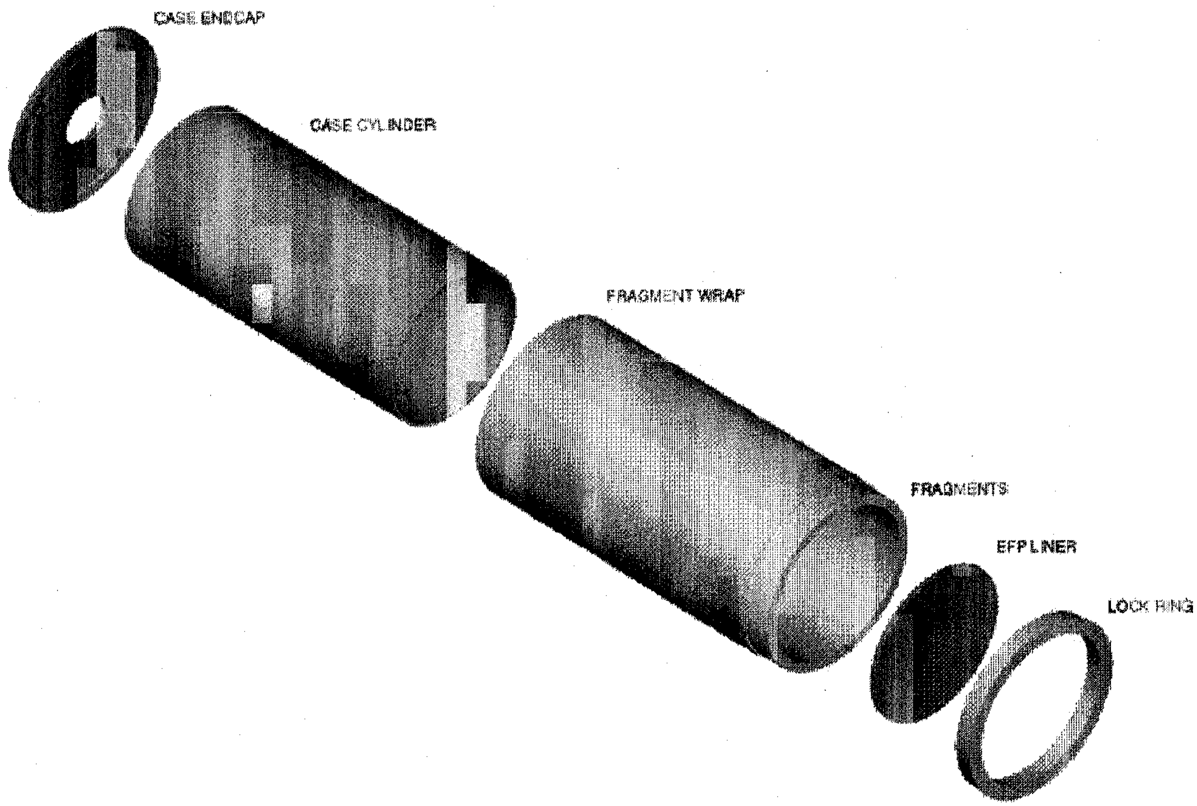
INDIAN HEAD NCE NATIONAL CENTER FOR ENERGETICS ESTABLISHED 1890

- Larger submunition than DPICM
- Better fragmentation control
- Proximity fuze
- Long stand-off shaped charge liner
- Reliable and uniform dispense
- Aerodynamic stability during final descent

Submunition Design

- Possible composite construction
- Arrives to the L/A/P facility as one piece
- Small fill port on aft
- Adaptable for multiple port fill manifold
- Final assembly is cylindrical, for easy packaging

Submunition Design



Formulation

- Fragmentation phenomenon is dependent upon shock physics
- Two IMAD/HE reports indicate that aluminized PBX can produce higher fragment velocities than non-aluminized PBX, if optimized

[1] NSWCDD TR-92/569 "Insensitive Munitions Advanced Development High Explosives Project: FY 91 Large-Scale Performance Testing of PBXC-129(Q)", Steve Collignon and Bill Burgess, February 1994.

[2] NSWCDD TR-98/45 "IMAD HE Project- Large Scale Fragmentation and Airblast Testing of Candidate General Purpose and Metal Accelerating Explosives", Bill Burgess, Steve Collignon, and John Leahy, June 1998.

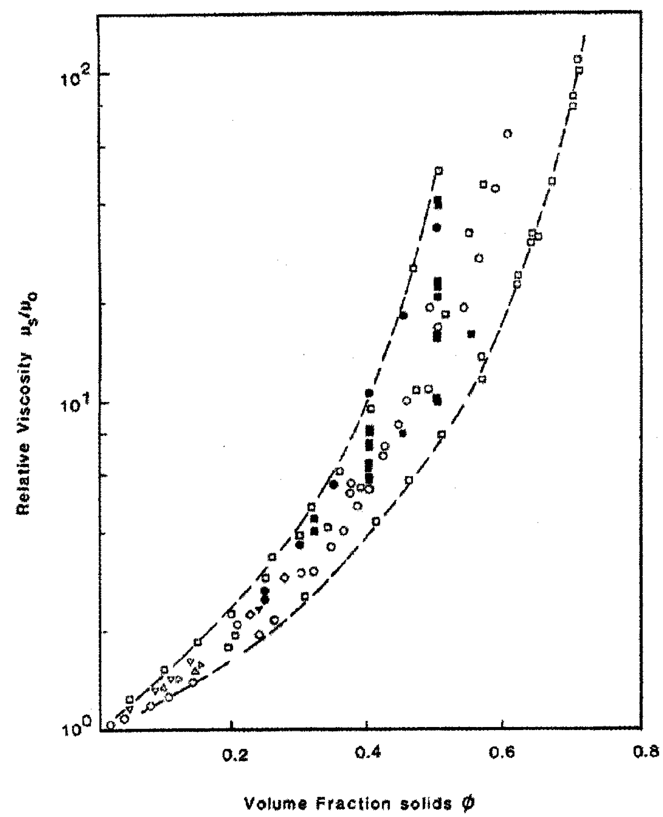
Formulation

- Experimental observation & explanation
  - Aluminum content *versus* fragment velocity
  - Impedance matching
- Approach
  - CYLEX testing of PBX formulations
  - Characterization of "late time event"
- Down-selection and Injection Loading
  - Plasticized polyurethane binder
  - HMX nitramine

Formulation

- We have investigated packing fraction maxima
  - using tri-modal particle size distribution allows a volume fraction of $\phi \geq 0.80$
  - relative viscosity function approaches infinity at maximum packing fraction

$$\mu_r = \mu_s/\mu_o = f(\phi/\phi_m)$$

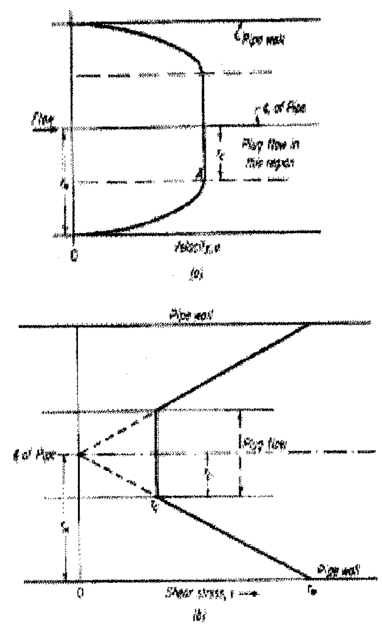


Formulation

- Taking advantage of previous injection loading work we did for ONR to ensure we have no shear induced particle migration. We want $d\phi/dt \longrightarrow 0$ in the limit as ϕ gets large.

$$d\phi/dt = f(a^2, \dot{\gamma}, 1/\mu_o)$$

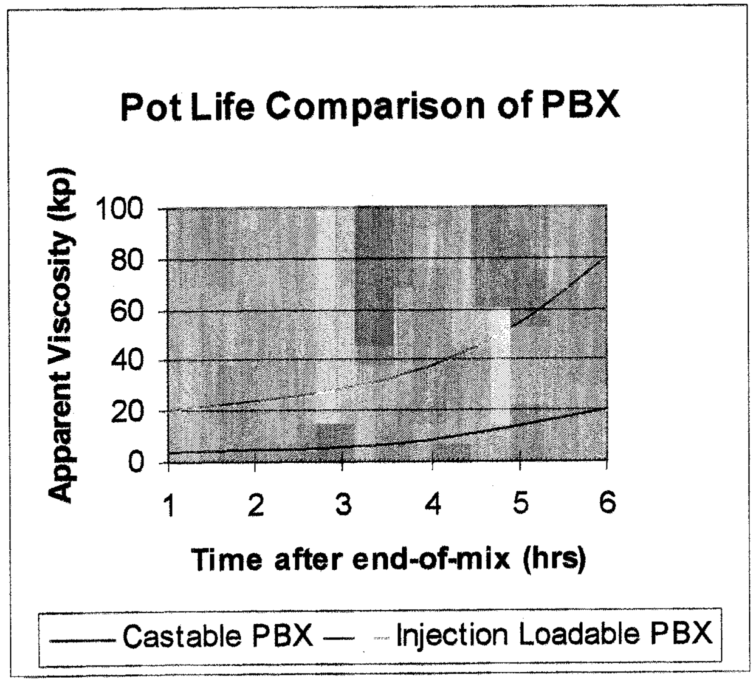
- We also want plug flow behavior, or Bingham plastic profiles



(a) typical Bingham plastic flow profile
(b) typical Bingham shear stress profile

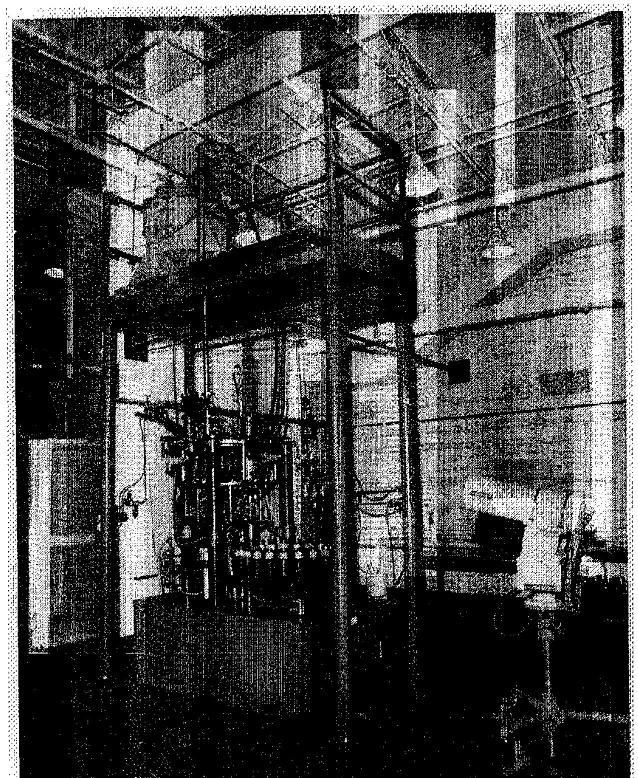
Formulation

- Expect this formulation to have a high end-of-mix viscosity
  - not castable
  - very good injection loadable material
- Processing "pot life" for PBX formulations is different
  - 20 kp limit for casting
  - 80 kp limit for injection loading



Process Design

- Minimize the L/D ratio of process plumbing
- Maximize size of process plumbing with respect to particle size (a/R)
- Use low pressure drop splitter plates
- Eliminate corner turns $\geq$ 45 degrees
- Eliminate abrupt contractions
- Use contraction ratios of about 2:1
- Use multi-port manifold to load more than one submunition per cycle



Process Control

NAVSEA INDIAN HEAD Surface Warfare Center Division

INDIAN HEAD NCE NATIONAL CENTER FOR ENERGETICS ESTABLISHED 1890

- Calculate flow as a function of ram displacement in time and geometry ($Q = f(u) = f(dx/dt)$)
- Utilize capillary rheometry algorithms to calculate
  - *apparent shear rate* (from flow rate)
  - *apparent shear stress* (from pressure)
  - *apparent viscosity*
- Monitor shear rate, and establish a control limit
- Monitor shear stress, and establish control parameters
- Monitor density at the contraction using a densitometer ($\rho = f(dm/dt)$), and establish control parameters
- Manipulative variable is ram displacement

Benefit

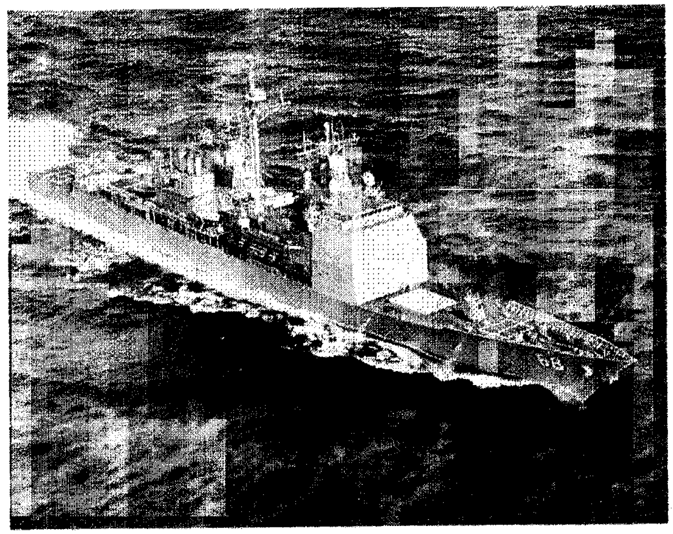
- Beneficial Economics
  - injection loading multiple submunitions per cycle
    - reduces unit cost and increases manufacturing rate
    - provides "pressed quality at a cast price"
- *"More Bang for the Buck"*
  - injection loaded PBX has nearly pressed density
  - replacing HMX with AL & improving performance
- Improving *Average* Fragmentation Velocity
  - observe only 4 % increase from PBXN-110 to PBXC-129
  - observe $\geq$ 8 % increase from PBXN-110 to "aluminized PBX"

Conclusion

- Submunitions will continue to be a vital part of the weapon inventory
- Future Navy submunitions will be larger than DPICM
- Future metal accelerating PBX formulations for fragmenting Navy submunitions will probably contain aluminum
- Injection loading is a proven technology that has potential to manufacture high quality PBX filled submunitions at high rate
- This technology will support RDT&E and production requirements for the surface strike mission

GEM S&T

Processing of R^3 Pressed Molding Powder



Kirk Newman - NSWCIHD
Ken Lee - THIOKOL
May Chan - NAWCWPNDIVCL

Thiokol Propulsion
From Cordant Technologies

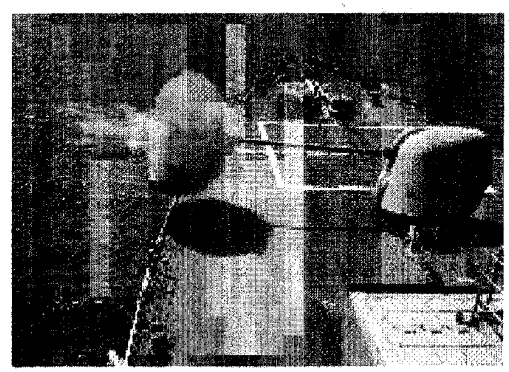
NAWC
NAVAL AIR WARFARE CENTER

NAVSEA
INDIAN HEAD

Success Criteria

<u>To demonstrate a CL-20 formulation that can satisfy</u>:

- ☺ Resource, reclamation, and reuse (R^3) criteria
- 😐 NSFS ERGM performance criteria
- ☹ Navy ISEA producibility assessment
- 😐 Navy explosive qualification instruction
- ☺ Candidacy requirements for other applications



Thiokol Propulsion
From Cordant Technologies

NAWC
NAVAL AIR WARFARE CENTER

Technical Approach

Comparison of CL-20 Formulations

Oxetane Copolymer TPE Binders	**Hydrolyzable Binders**
• Energetic binder permits lower CL-20 concentration	• Binder permits easy recovery of CL-20 and eliminates pollution burden of demilitarization
• TPE permits recovery of CL-20 and eliminates demilitarization	• Binder can not be reused
• TPE can be recovered for reuse	• Binder is low cost

Thiokol Propulsion
From Cordant Technologies

Technical Approach

Comparison of Ingredients & Technologies

- TPE is an oxetane copolymer
- TPE has two sources, Thiokol and Aerojet
- Processes for making molding powder include traditional slurry kettle mixing and precipitation or twin screw compounding & extrusion.
- Hydrolyzable monomer is either *Witco 10PE-37* hydroxyl-terminated polyester, or *Rucoflex* from RUCO Polymer Corp.
- Lysine diisocyanate methyl ester is made by Kyowa Hakko Kogyo Co. Ltd. in Japan, as the market demands.
- Process is either traditional or a new fluorocarbon fluid slurry kettle mixing and precipitation.

Thiokol Propulsion
From Cordant Technologies

Explosives

Basis for comparison and down-selection:

- Theoretical detonation properties
- Laboratory scale safety test results on molding powder (impact, friction, ESD, etc.)
- Molding powder quality (composition, SEM, bulk density, free flowing, hygroscopicity, etc.)
- Shock sensitivity (IHE gap or LSGT)
- Cook-off sensitivity (VCCT)
- Measured detonation properties (as compared to PBXW-11)
- Ease of demilitarization
- Pressing evaluation (bulk density > 0.8 g/cc, % TMD @ 20 kpsi, no heat, no vacuum, etc.)
- Material and processing costs

Explosives

Formulation Summary

- 13 different CL-20 TPE formulations
- 3 different hydrolyzable formulations
- All will perform better than PBXW-11
- All are R^3 formulations

NAVSEA INDIAN HEAD

Explosives

Progress on down-selection of formulations

	GEM-106	GEM-110	GEM-113B	CL-1	CL-2	CL-3
Theoretical Detonation Properties	✓	✓	✓	✓	✓	✓
Lab Safety Tests	✓	✓	✖	✖	✓	✓
Interim Hazard Classification	✓		✖	✖	✖	✓
Molding Powder Quality	✓	✓	✖	✓	✓	✓
Shock Sensitivity	?	?				?
Cook-off Sensitivity	✓	✖	✖			
Measured Detonation Properties	✓					✓
Lab CL-20 Recovery	✓	✓	✓	✓	✓	✓
Lab Binder Recovery	✓	✓	✓	✖	✖	✖
Aging Study	✓			✓		
R3 scale-up demonstration	✓					
Pressing Evaluation	✓	✓		✓	✓	✓
Pressing into M80	✓					✓
Pressing at LSAAP	?					✖
NSFS ERGM P3I Liner Tests	✓					
NSFS ERGM P3I Fragmentation Tests	?					?
Material & Processing Cost	?					✓

Thiokol Propulsion
From Cordant Technologies

NAWC Weapons Division
NAVAL AIR WARFARE CENTER

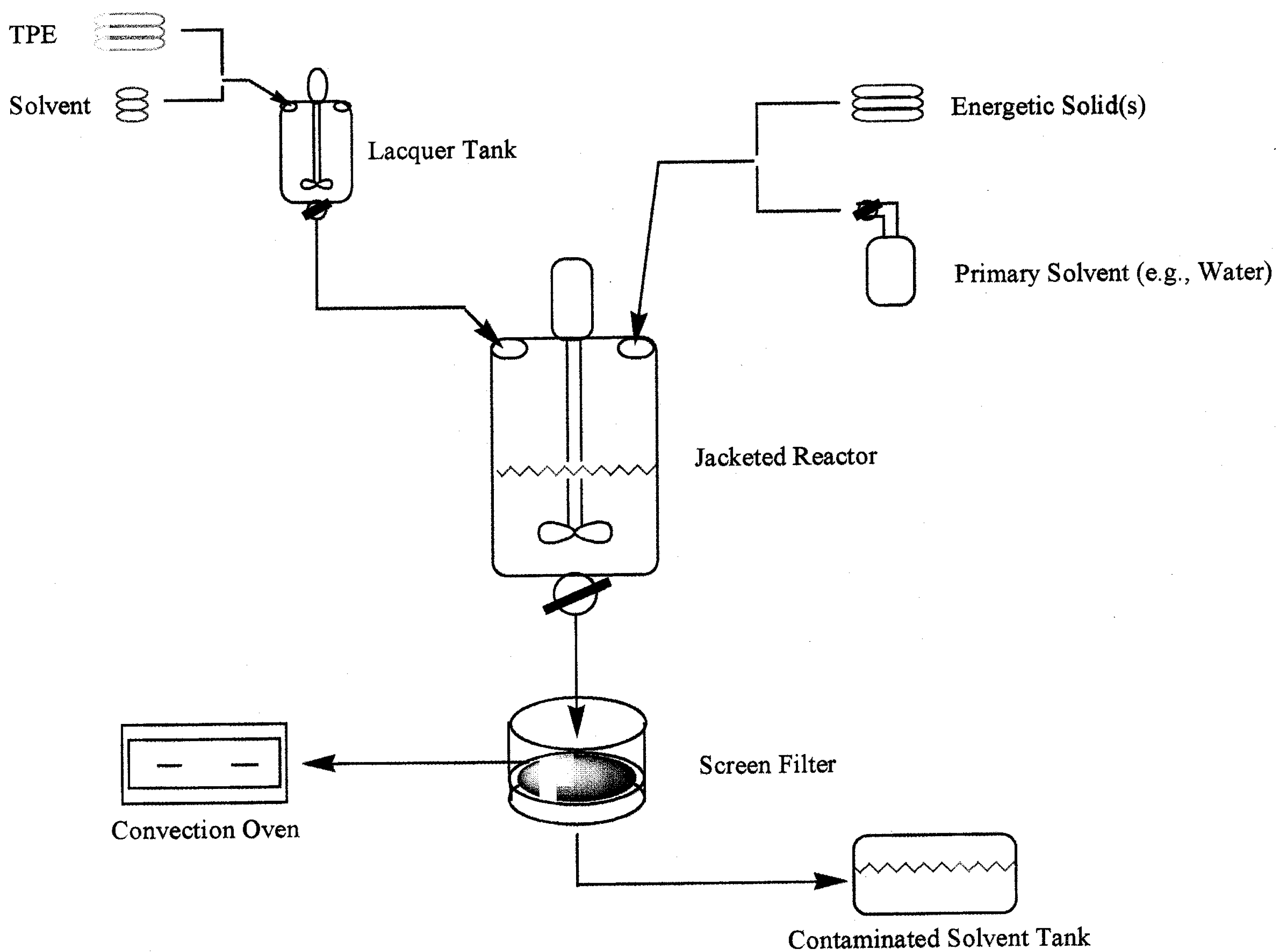
Issues

- Reproducibility and Sensitivity of CL-20
  - *crystal imperfections*
  - *polymorph conversion*
  - *friction, impact, and shock sensitive*
- Quality and Reuse of Molding Powder
  - *defining process parameters that produce good powder*
  - *effectiveness of R^3 processes*

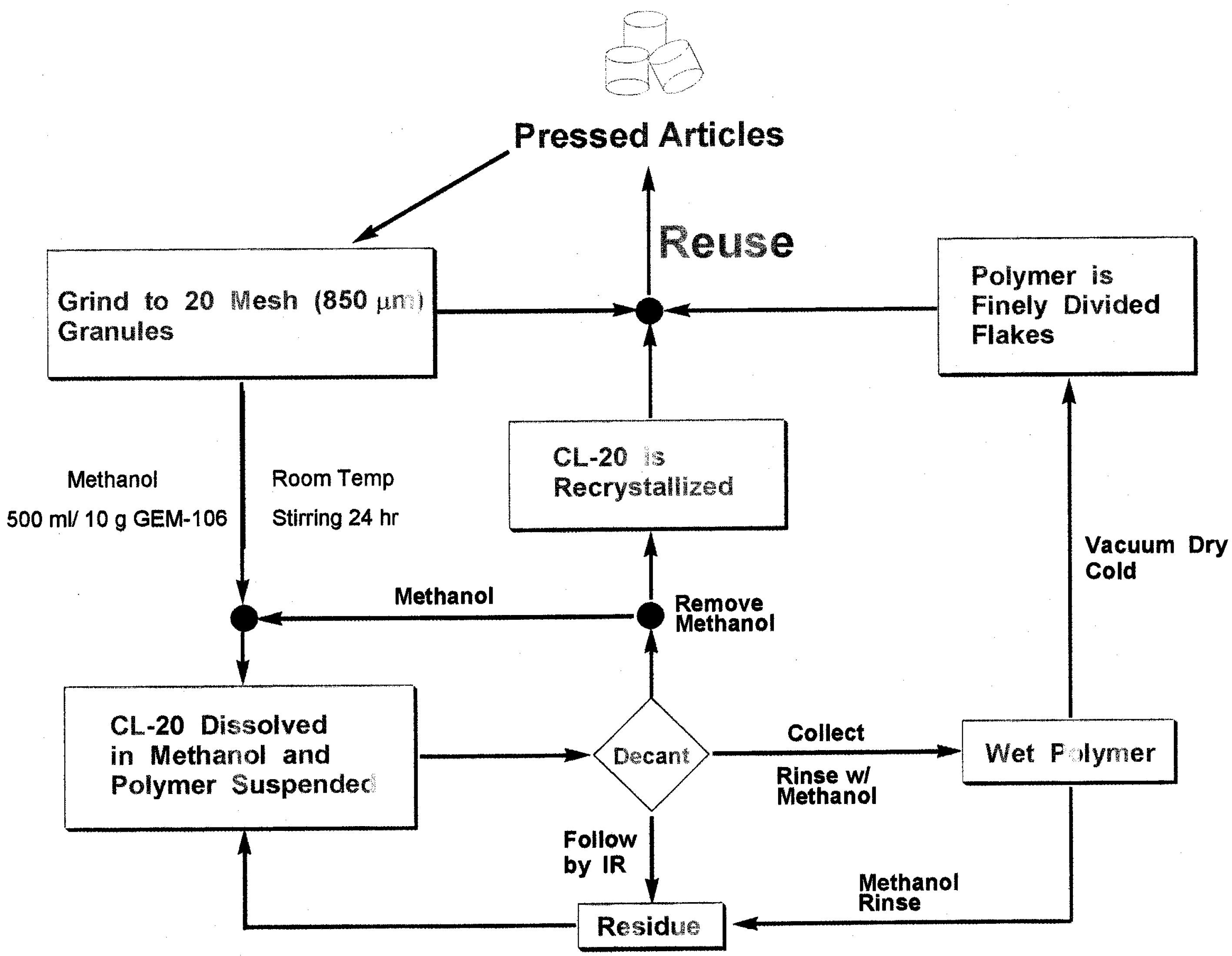
Thiokol Propulsion
From Cordant Technologies

NAWC
NAVAL AIR WARFARE CENTER

Schematic of the Water Slurry Process



Recovery Method for TPE Formulations



Shock Sensitivity Issue

- Improve CL-20 Crystal Quality
  - *Thiokol*
  - *Navy MANTECH*
- Improve Formulation(s)
  - *use recrystallized CL-20*
  - *use higher concentration of "fine" CL-20*
  - *change processing technique*
  - *change TPE from BAMO/NMMO to BAMO/PGN*
  - *substitute HMX for CL-20*

Thiokol Propulsion
From Cordant Technologies

NAWC Weapons Division
NAVAL AIR WARFARE CENTER

NAVSEA INDIAN HEAD

Formulation Improvements
Sensitivity Tests Results

- Reclaimed CL-20 has expected properties

	Reclaimed CL-20 from GEM-106	Unground CL-20 Lot 218-6-008	Ground CL-20 Lot 218-6-010
Impact Sensitivity (50% ht in cm) RDX std = 18.9	16.0	14.0	17.6
Friction Sensitivity (N) PETN std = 48	60	48	84
DSC Onset of Exotherm (°C)	238.9	239.3	235.8
VTS (ml/g)	0.46	0.0	0.11

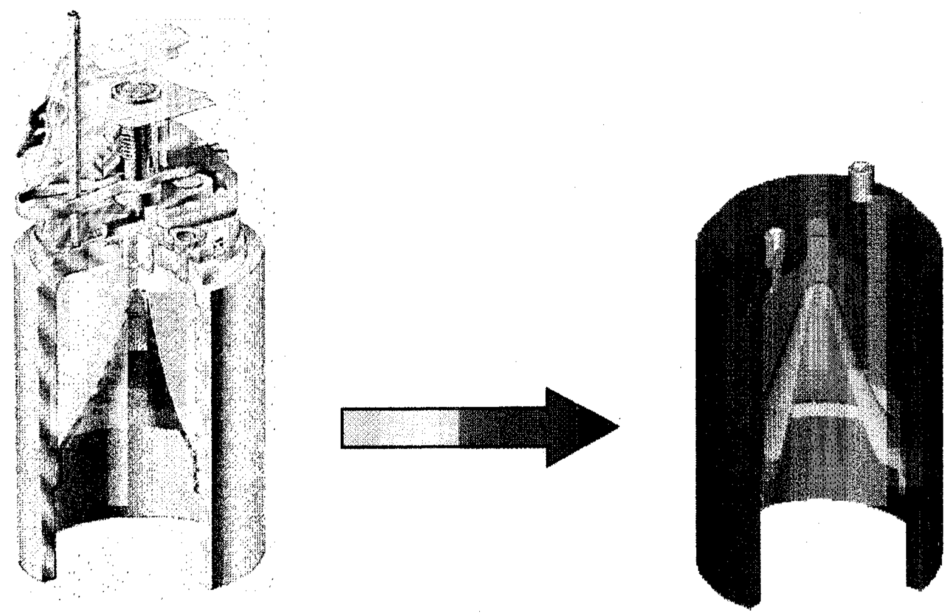
Formulation Improvements
Sensitivity Tests Results

- GEM-106 powder via traditional method
  - impact sensitivity is about 30 to 38 cm (RDX = 20 cm)
  - friction sensitivity is about 160 N (RDX = 160 N)

- GEM-106 powder processed via new method
  - *impact sensitivity is improved by about 10%*
  - *friction sensitivity is dramatically improved, by about 100%*

Formulation Improvements
Arena Tests Results

- GEM-106 powder pressed at 98% TMD
- Improved RHA penetration by 10% over PBXW-11 @ HOB
- Improved average fragment velocity by only 4%



Further Development

Explosive Formulation	Technology				
	R^3 nitramine	R^3 binder	Demonstrate CL20 formulation is qualifiable	Demonstrate R^3 formulation can be qualifiable	Demonstrate high speed automated pressing @ LSAAP
GEM-106 (CL20/BAMO-NMMO)	99	99	Shock sensitivity problems	Shock sensitivity problems	99
GEM-116 (CL20/BAMO-PGN)	00	00	00	00	00
GEM-117 (HMX/BAMO-PGN)	00	00	00	00	00
GEM-114 (HMX/BAMO-NMMO)	99	99	00	00	00
CL-3 (CL20/Hydrolyzable)	99	N/A	Shock sensitivity problems	Shock sensitivity problems	Sticking problems
CL-4 (HMX/Hydrolyzable)				Difficult to justify as S&T	

Thiokol Propulsion

From Cordant Technologies

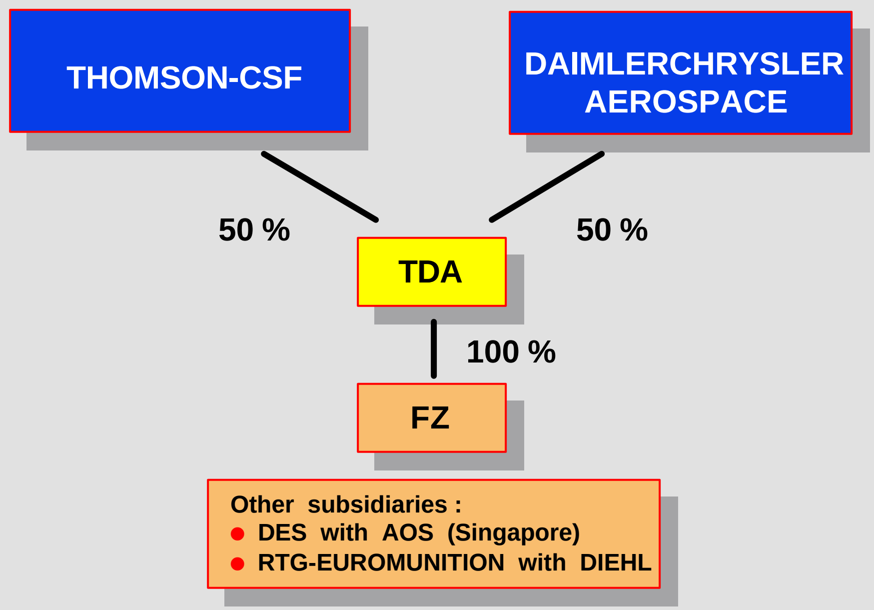
ROCKET - ASSISTED AMMUNITION TECHNOLOGIES for 120 mm MORTARS

MUNITIONS TECHNOLOGY SYMPOSIUM

In Pleasanton on April 11 - 12, 2000

TDA

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS



- **Historical European ordnance leader since WW 1**
  - Fuzes
  - Mortars
  - Rockets
  - Warheads
  - Anti-tank systems

TDA AND ROCKET ASSISTED TECHNOLOGIES

- TDA spent half century to investigate various RAP technologies
- TDA has explored :
  - Army applications (120 mm mortars, 155 and 203 mm SPH)
  - Naval applications (100 mm French Navy gun)
  - Missile applications (140 mm missile caliber)
- TDA has identified and demonstrated four RAP technology areas :
  - Impulse in flight technology : 120 mm mortar RAP (13 km)
  - Sustained rocket assisted technology : 120 mm mortar RAP-VLR (17 km)
  - "Isostatic" technology : 120 mm mortar and 155 mm gun projectiles
  - Ramjet technology : 155 mm gun projectile

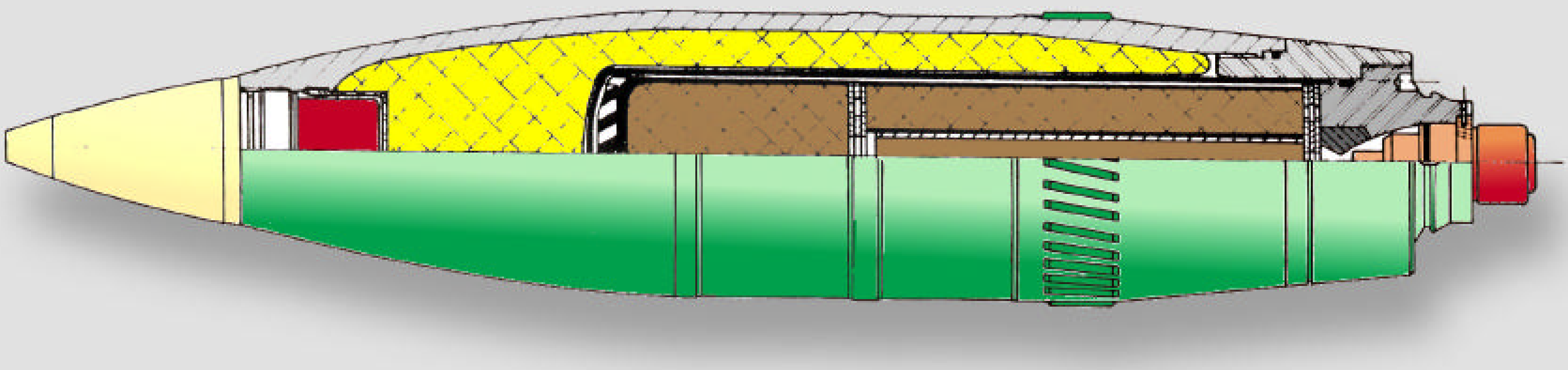
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

PROJECTILE	RAP	RAP- VLR	Isostatic RAP	Ramjet
CALIBER	*120 mm*	*120 mm*	*120 & 155 mm*	*155 mm*
RANGE	*13 km*	*17 km*	*13 km (120 mm)* *32 km (155 mm)*	*35 km*
MORTAR & GUN TYPE	*Rifled*	*Smooth & Rifled*	*Rifled*	*Rifled*
“g” LEVEL	*9 000 g*	*6 000 g*	*9 000 g (120 mm)* *11 000 g (155 mm)*	*11 000 g*
BURNING TIME	*3.5 s*	*30 s*	*8 s (120 mm)*	*12 s*
STATUS	*Serial production*	*Feasibility*	*Feasibility*	*Feasibility*

TDA

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

120 mm RAP

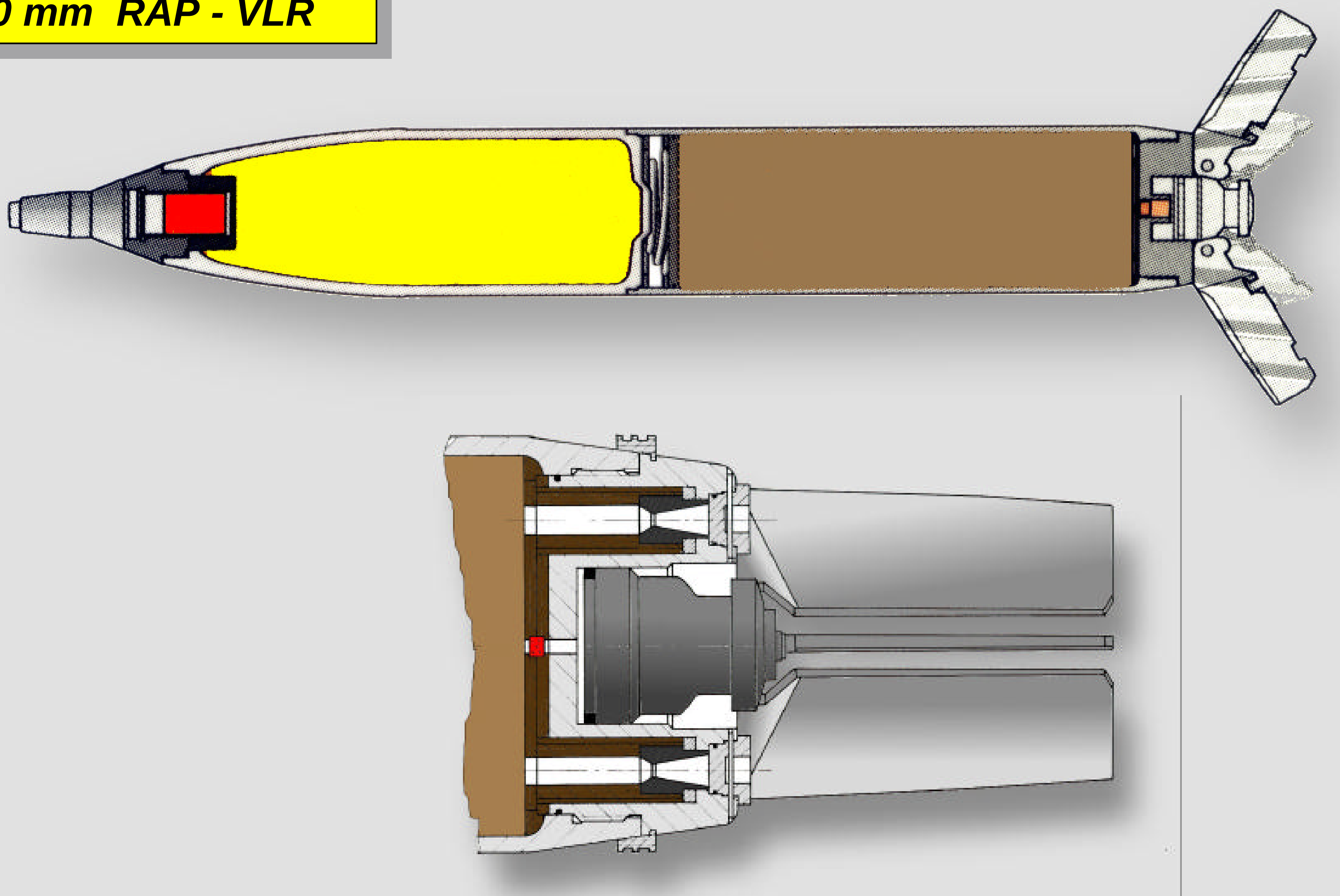


ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

PROJECTILE	RAP	RAP- VLR	Isostatic RAP	Ramjet
CALIBER	*120 mm*	*120 mm*	*120 & 155 mm*	*155 mm*
RANGE	*13 km*	*17 km*	*13 km (120 mm)* *32 km (155 mm)*	*35 km*
MORTAR & GUN TYPE	*Rifled*	*Smooth & Rifled*	*Rifled*	*Rifled*
"g" LEVEL	*9 000 g*	*6 000 g*	*9 000 g (120 mm)* *11 000 g (155 mm)*	*11 000 g*
BURNING TIME	*3.5 s*	*30 s*	*8 s (120 mm)*	*12 s*
STATUS	*Serial production*	*Feasibility*	*Feasibility*	*Feasibility*

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

120 mm RAP - VLR

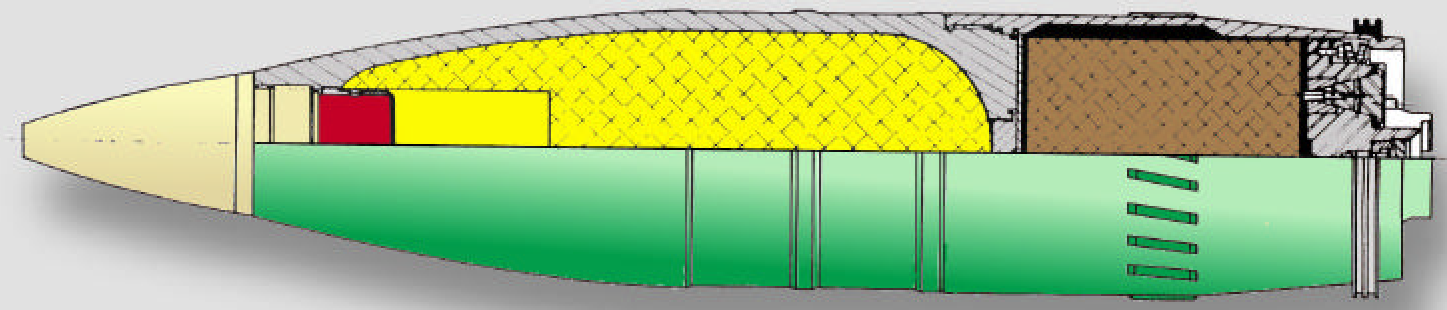


ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

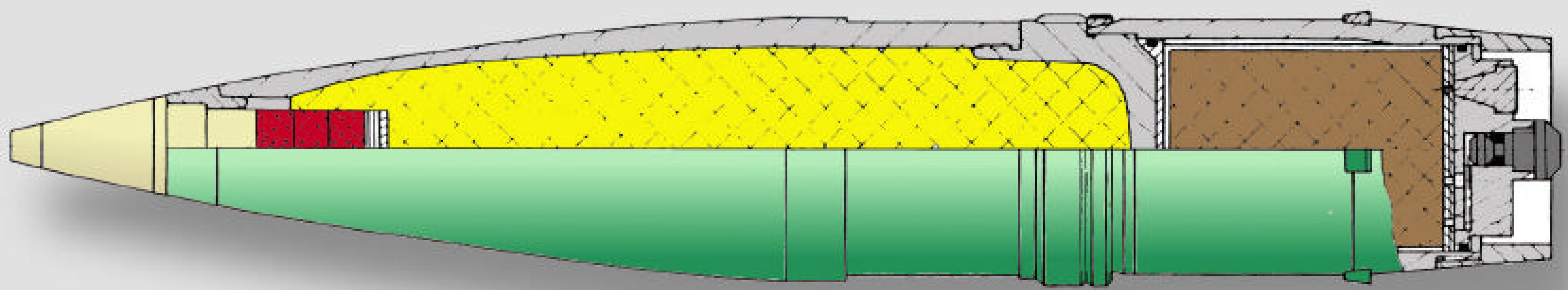
PROJECTILE	RAP	RAP- VLR	Isostatic RAP	Ramjet
CALIBER	*120 mm*	*120 mm*	*120 & 155 mm*	*155 mm*
RANGE	*13 km*	*17 km*	*13 km (120 mm)* *32 km (155 mm)*	*35 km*
MORTAR & GUN TYPE	*Rifled*	*Smooth & Rifled*	*Rifled*	*Rifled*
“g” LEVEL	*9 000 g*	*6 000 g*	*9 000 g (120 mm)* *11 000 g (155 mm)*	*11 000 g*
BURNING TIME	*3.5 s*	*30 s*	*8 s (120 mm)*	*12 s*
STATUS	*Serial production*	*Feasibility*	*Feasibility*	*Feasibility*

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

120 mm isostatic RAP



155 mm isostatic RAP



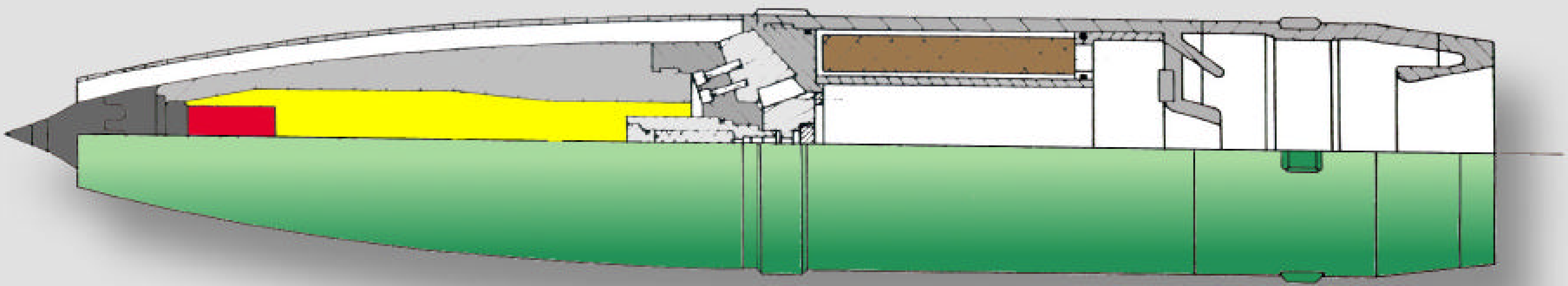
TDA

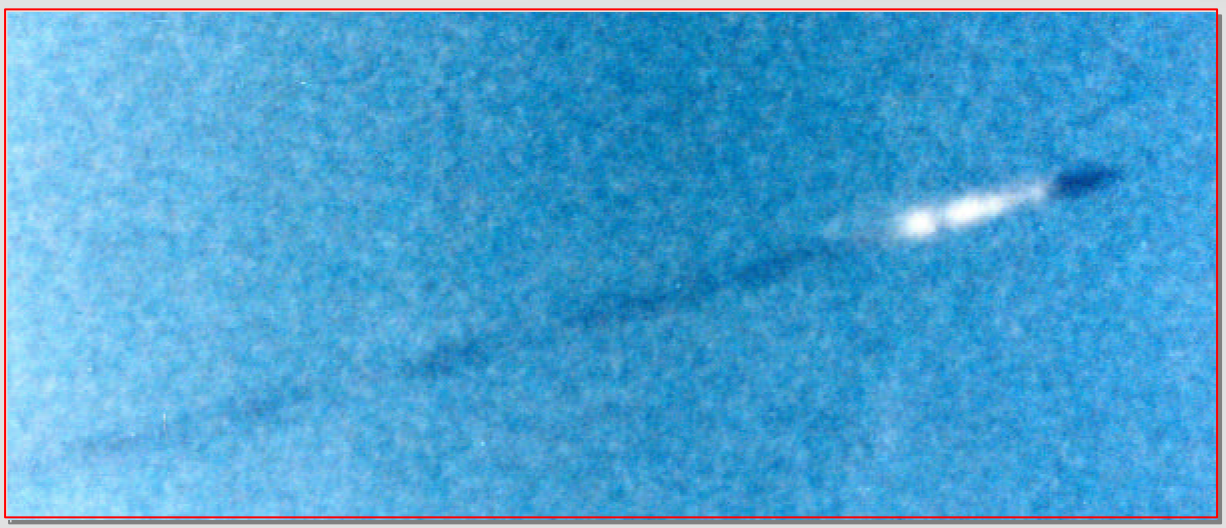
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

PROJECTILE	RAP	RAP- VLR	Isostatic RAP	Ramjet
CALIBER	*120 mm*	*120 mm*	*120 & 155 mm*	***155 mm***
RANGE	*13 km*	*17 km*	*13 km (120 mm)* *32 km (155 mm)*	***35 km***
MORTAR & GUN TYPE	*Rifled*	*Smooth & Rifled*	*Rifled*	***Rifled***
“g” LEVEL	*9 000 g*	*6 000 g*	*9 000 g (120 mm)* *11 000 g (155 mm)*	***11 000 g***
BURNING TIME	*3.5 s*	*30 s*	*8 s (120 mm)*	***12 s***
STATUS	*Serial production*	*Feasibility*	*Feasibility*	***Feasibility***

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

155 mm ramjet projectile





ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

120 mm RAP

- **Purpose :**
  - **Increase range by 60% (from 8 km to 13 km)**
- **Requirement :**
  - **Keep common logistics with 120 mm mortar projectile family (Same shape, same weight, same propellant charge, same ballistic)**
- **Main challenges :**
  - **Resist at very cold temperature for the DB propellant grain :**
    - **To axial (9 000 g) and radial (250 000 rd/s²) accelerations**
    - **To rotation speed (12 000 rev/mn)**
  - **Keep warhead at acceptable temperature during the DB propellant combustion**
  - **Maintain combustion characteristics under high rotation speed**

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

A LARGE AMMUNITION FAMILY

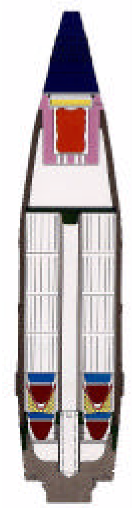
HE

WP

PRAC

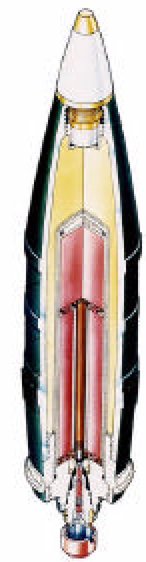
PRAB

ILLUM



DPICM

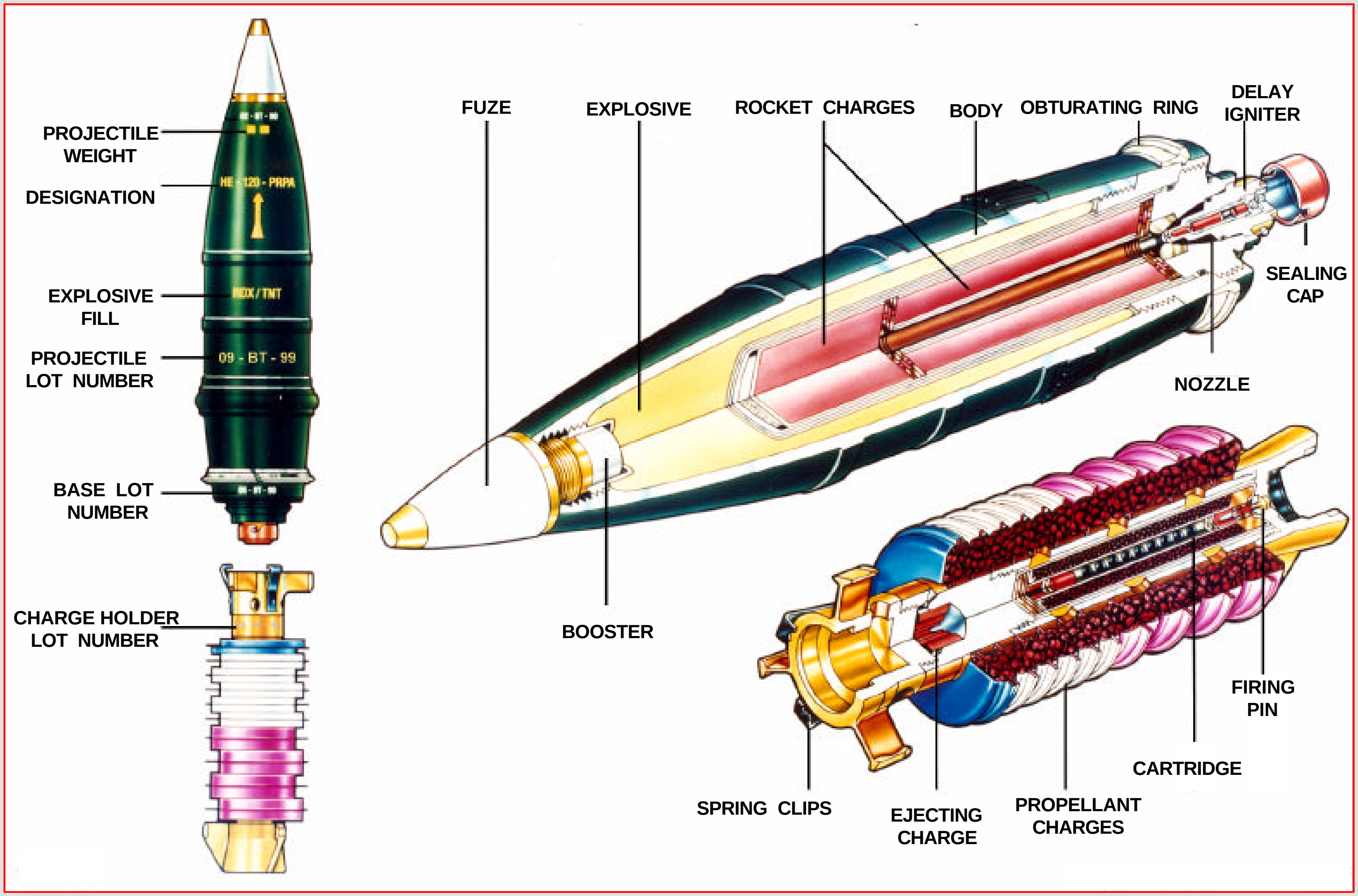
ROCKET ASSISTANCE



RANGE 13 km

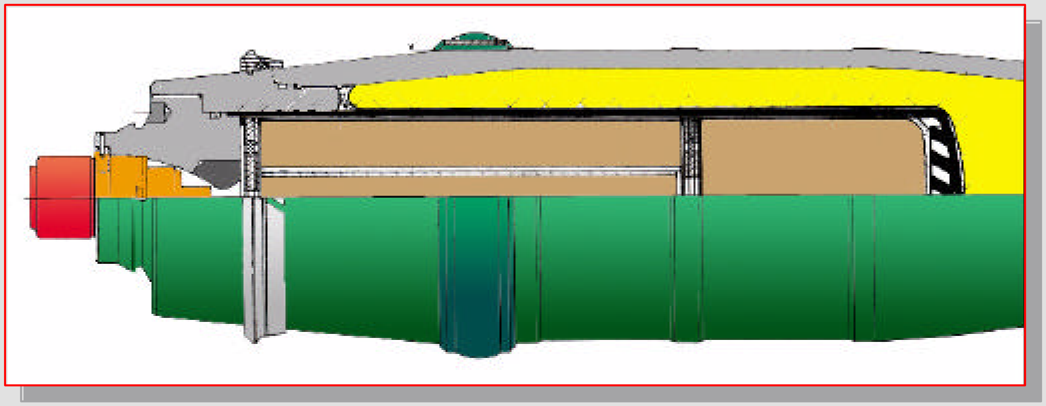
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

HIGH EXPLOSIVE (WITH ROCKET ASSISTANCE) AMMUNITION : HE-120 mm - RAP



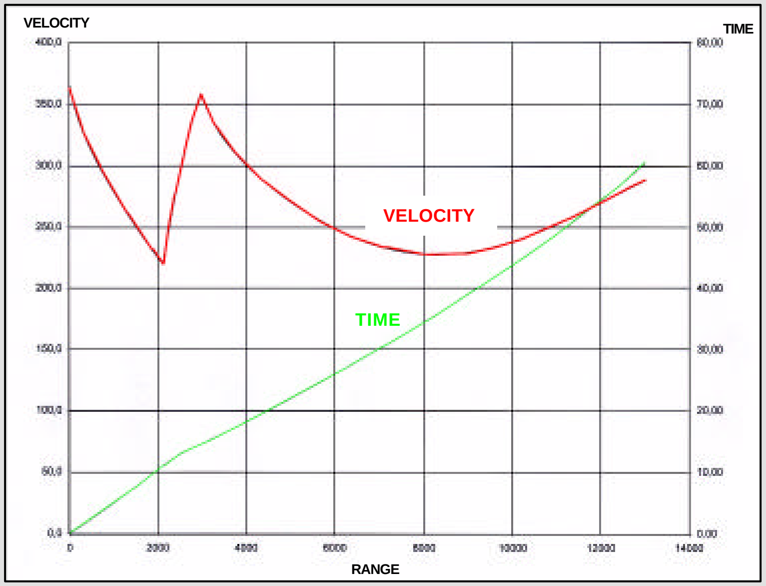
TDA

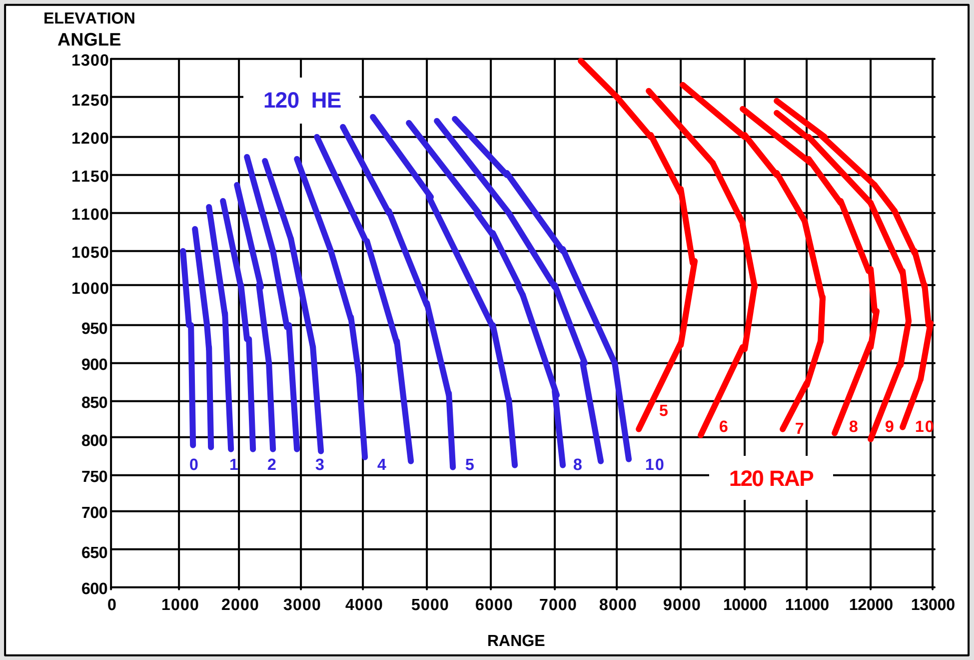
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS



ROCKET ASSISTED PROJECTILE

- 1.3 kg of D.B propellant
- Burning time : 3.5 s
- Impetus : 2 500 N.s
- Ignition delay : 11 s
- « g » level : 11 000





120 mm RAP

- Purpose :
  - Increase range by 60% (from 8 km to 13 km)
- Requirement :
  - Keep common logistics with 120 mm mortar projectile family (Same shape, same weight, same propellant charge, same ballistic)
- **Main challenges :**
  - **Resist at very cold temperature for the DB propellant grain :**
    - **To axial (9 000 g) and radial (250 000 rd/s²) accelerations**
    - **To rotation speed (12 000 rev/mn)**
  - **Keep warhead at acceptable temperature during the DB propellant combustion**
  - **Maintain combustion characteristics under high rotation speed**

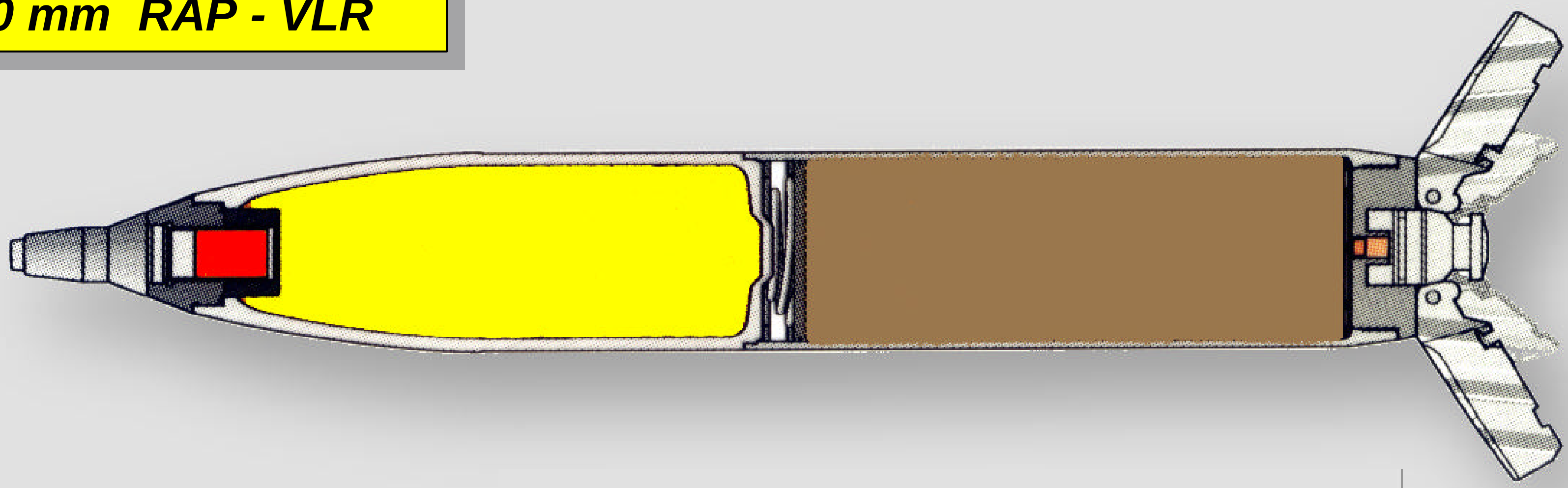
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

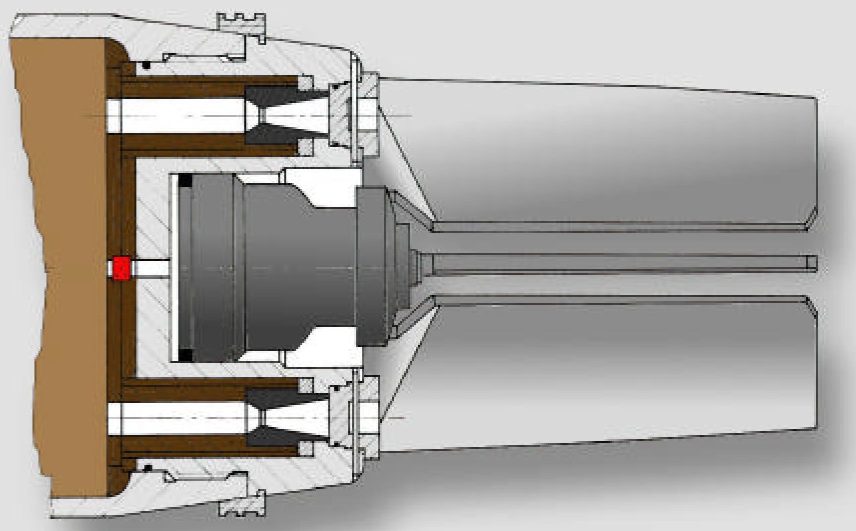
120 mm RAP - VLR

- **Purpose :**
  - **Match 105 mm light gun range**
- **Requirements :**
  - **Compatible with TDA 120 mm universal mortar tube**
  - **Compatible with 120 mm smooth mortar tube**
- **Results data :**
  - **Flight tests in January 1986**
    - **17 km range demonstrated in GAVRES French MOD Center**
  - **French Army contract completed in 1991**
- **Main challenges :**
  - **Resist axial acceleration (9 000 g) at very cold temperature for the propellant grain**
  - **Fins resistance during the acceleration phase**
  - **Fins correct opening**
  - **Temperature control at aft end during the combustion phase (30 s)**

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

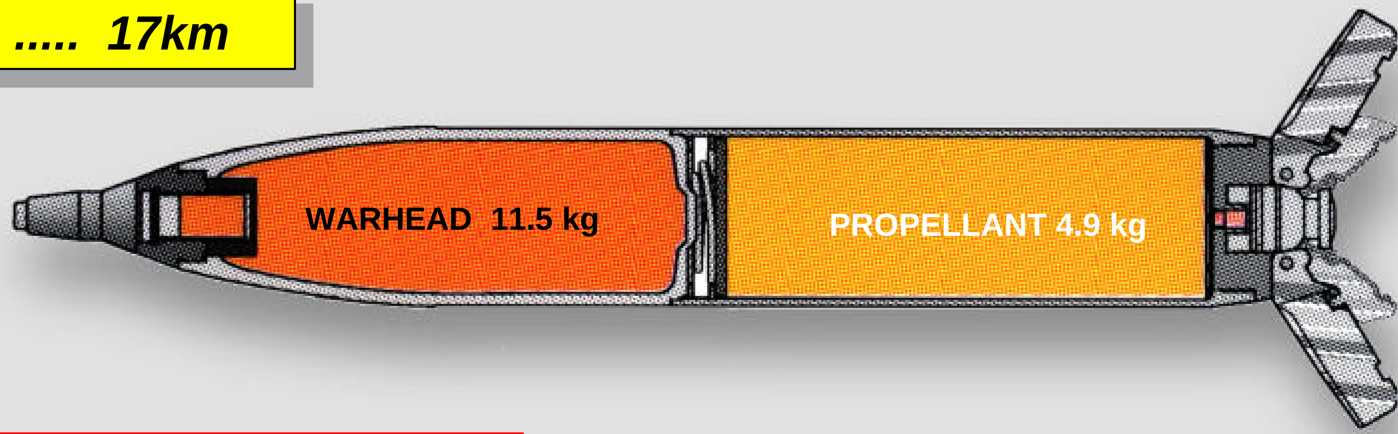
120 mm RAP - VLR





ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

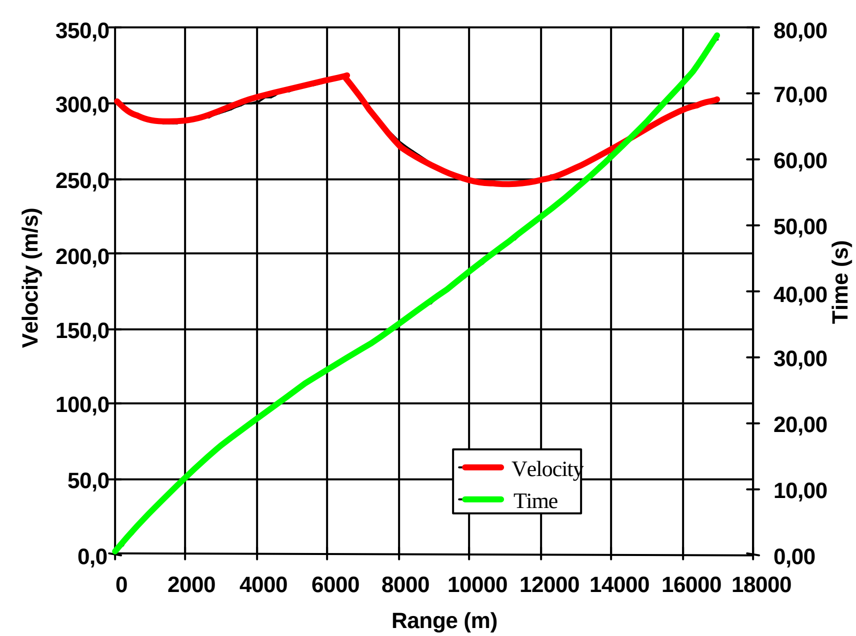
RANGE 17km



DATA

- WEIGHT : 24 kg
- LENGTH : 954 mm
- RANGE : 17 000 m
- FINS STABILIZED
- PROPELLANT :
  - WEIGHT : 4.9 kg
  - BURNING TIME : 30 s
  - DELAY : 0 s
- MUZZLE VELOCITY : 302 m/s
- MAX PRESSURE : 120 MPa

IN DEVELOPMENT



TDA

120 mm RAP - VLR

- Purpose :
  - Match 105 mm light gun range
- Requirements :
  - Compatible with TDA 120 mm universal mortar tube
  - Compatible with 120 mm smooth mortar tube
- **Results data :**
  - **Flight tests in January 1986**
    - **17 km range demonstrated in GAVRES French MOD Center**
  - **French Army contract completed in 1991**
- Main challenges :
  - Resist axial acceleration (9 000 g) at very cold temperature for the propellant grain
  - Fins resistance during the acceleration phase
  - Fins correct opening
  - Temperature control at aft end during the combustion phase (30 s)

ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

FLIGHT TESTS

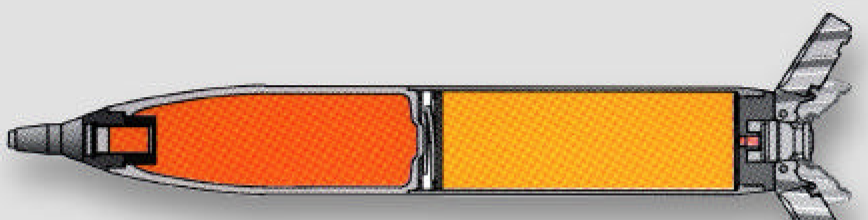
120 mm RAP - VLR

- Purpose :
  - Match 105 mm light gun range
- Requirements :
  - Compatible with TDA 120 mm universal mortar tube
  - Compatible with 120 mm smooth mortar tube
- Results data :
  - Flight tests in January 1986
    - 17 km range demonstrated in GAVRES French MOD Center
  - French Army contract completed in 1991
- **Main challenges :**
  - **Resist axial acceleration (9 000 g) at very cold temperature for the propellant grain**
  - **Fins resistance during the acceleration phase**
  - **Fins correct opening**
  - **Temperature control at aft end during the combustion phase (30 s)**

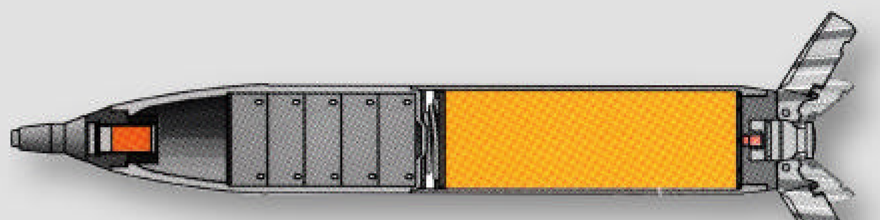
ROCKET- ASSISTED AMMUNITION TECHNOLOGIES FOR 120 mm MORTARS

GROWTH POTENTIAL

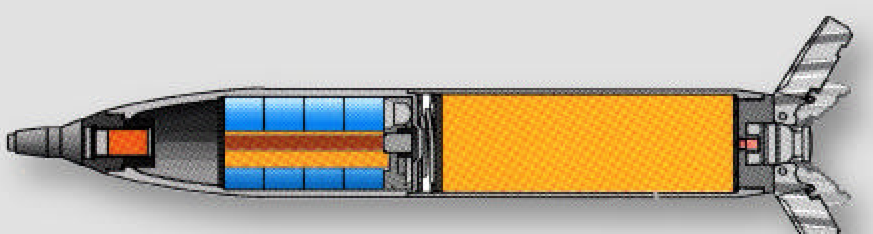
- **Carry lethal or non lethal payloads**
- **Flexible design trading range versus payload**
- **Increase kill probability by using smart fuzes (SAMPRASS fuze)**



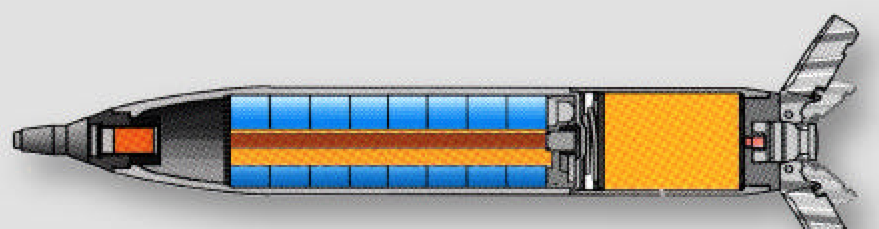
RAP - VLR
with HE warhead



RAP - VLR
with non lethal payload



RAP - VLR
with DPICM



RAP - VLR
with DPICM

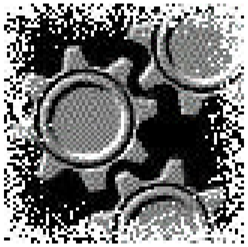
CONCLUSION

- **TDA will present other RAP technologies in next future**
- **TDA is looking for cooperation with U.S experts**

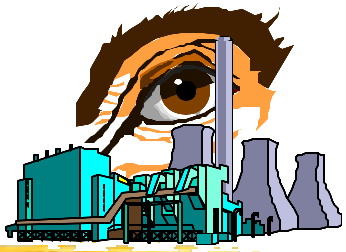
Machine Vision for Industrial Automation

Machine Vision for Industrial Automation

Mitch Stone

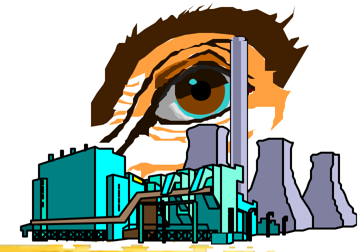


Machine Vision for Industrial Automation

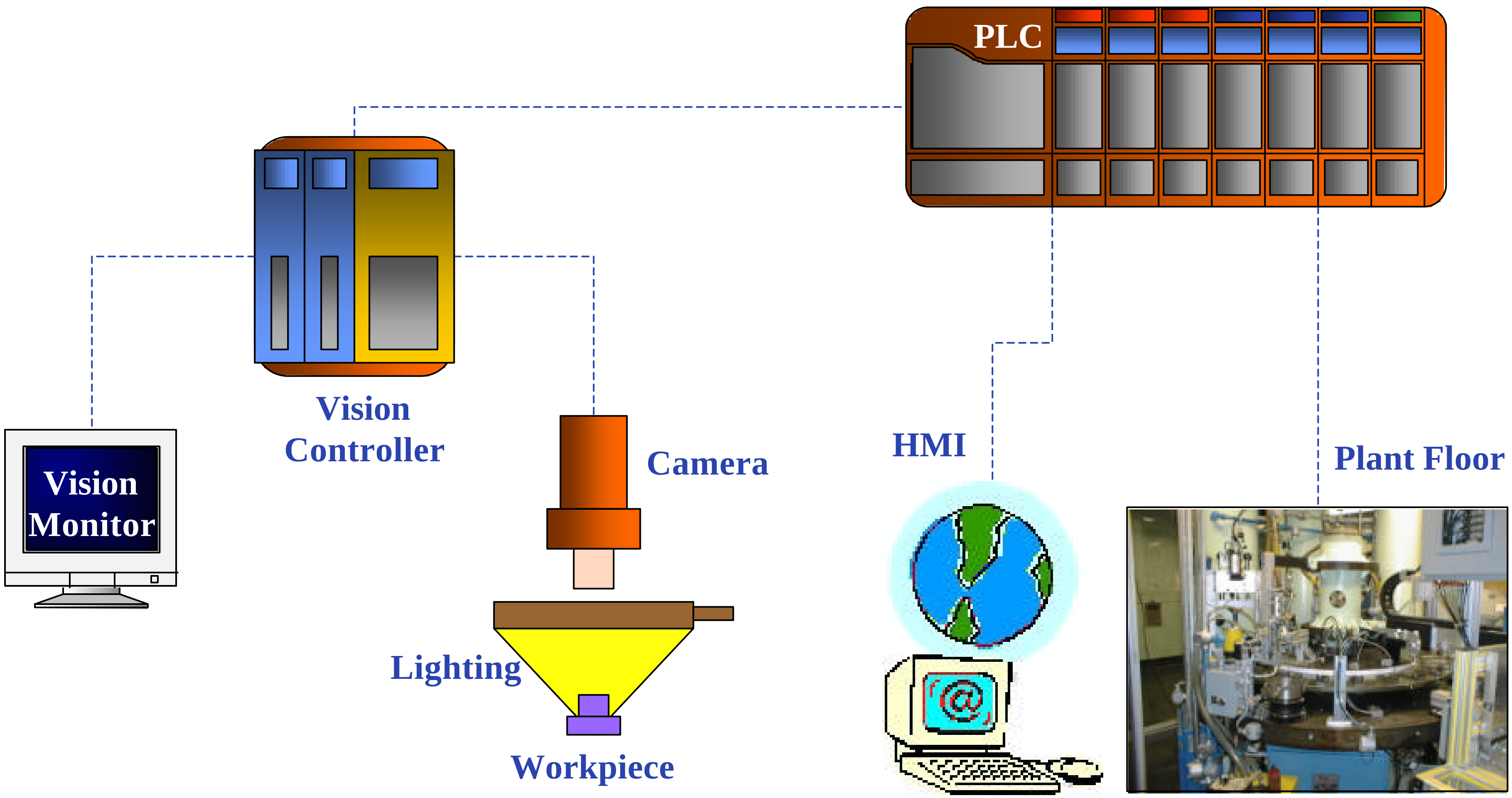


- ☑ History and Evolution
- ☑ Typical Machine Vision System
- ☑ Machine Vision Technology
- ☑ Machine Vision Tools
- ☑ Human Machine Interface

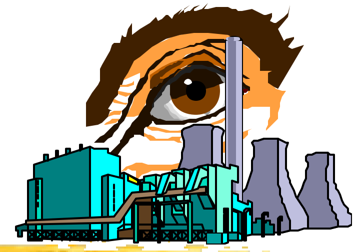
History and Evolution



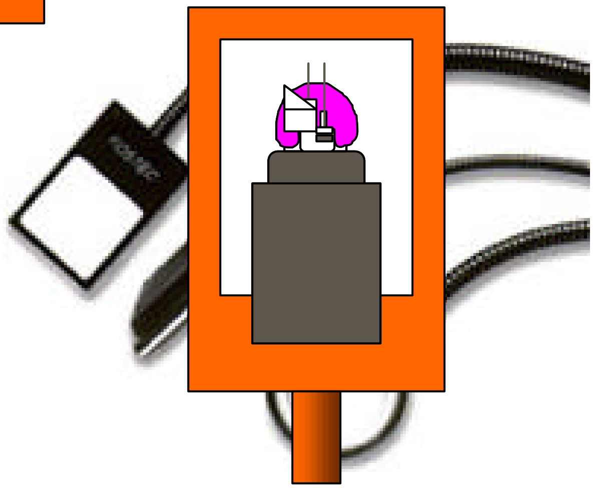
Typical Machine Vision System



Lighting



FIBER OPTIC ILLUMINATION

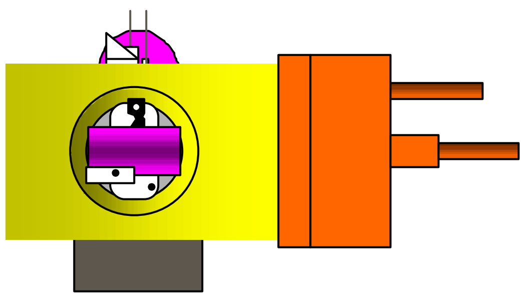


- ☑ Light Source
- ☑ Backlights
- ☑ Fiber Optic Bundles

Lighting

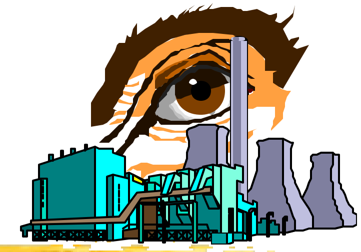
FIBER OPTIC ILLUMINATION

- ☑ Light Source

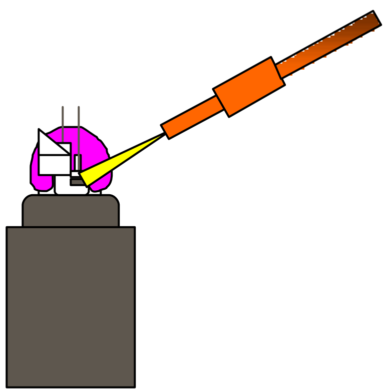


- ☑ Backlights
- ☑ Lightlines

Lighting

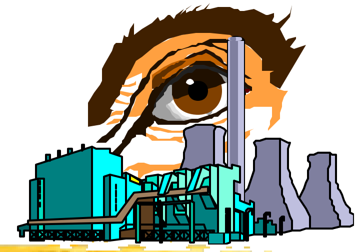


FIBER OPTIC ILLUMINATION

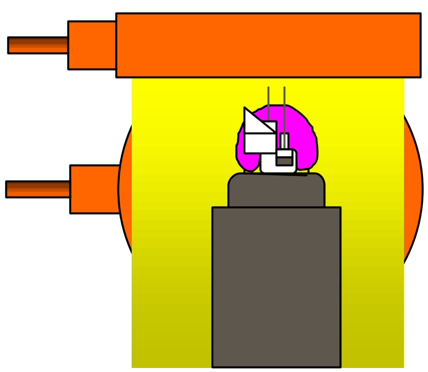


- ☑ Light Source
- ☑ Backlights
- ☑ Lightlines
- ☑ Goosenecks

Lighting



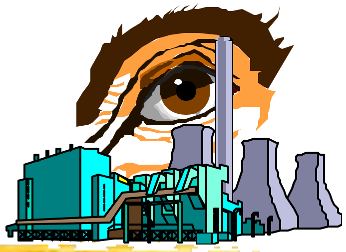
FIBER OPTIC ILLUMINATION



- ☑ Light Source

- ☑ Backlights
- ☑ Lightlines
- ☑ Goosenecks
- ☑ Ringlights

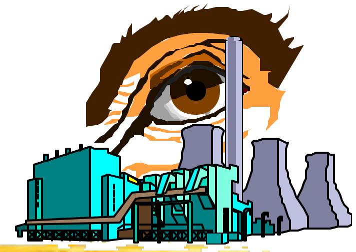
Lighting



FIBER OPTIC ILLUMINATION

- ☑ Light Source
- ☑ Backlights
- ☑ Lightlines
- ☑ Goosenecks
- ☑ Ringlights
- ☑ Accessories

Lighting

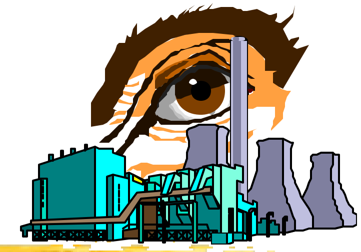


INTERNAL LIGHT ADJUSTMENTS

- **Further Enhancements to Lighting Within Vision Controller**

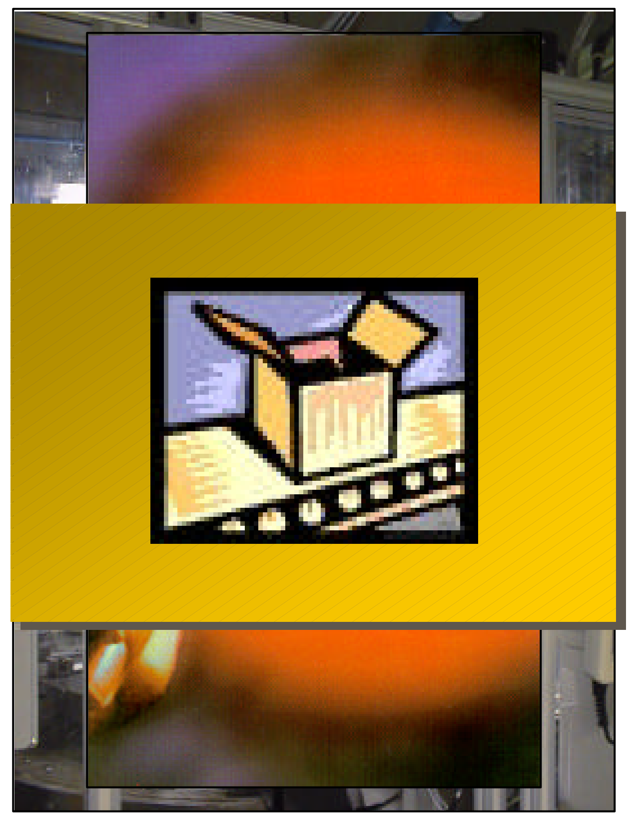
  ➡ **Light Reference**

Camera and Lenses



CAMERA AND LENS SELECTION

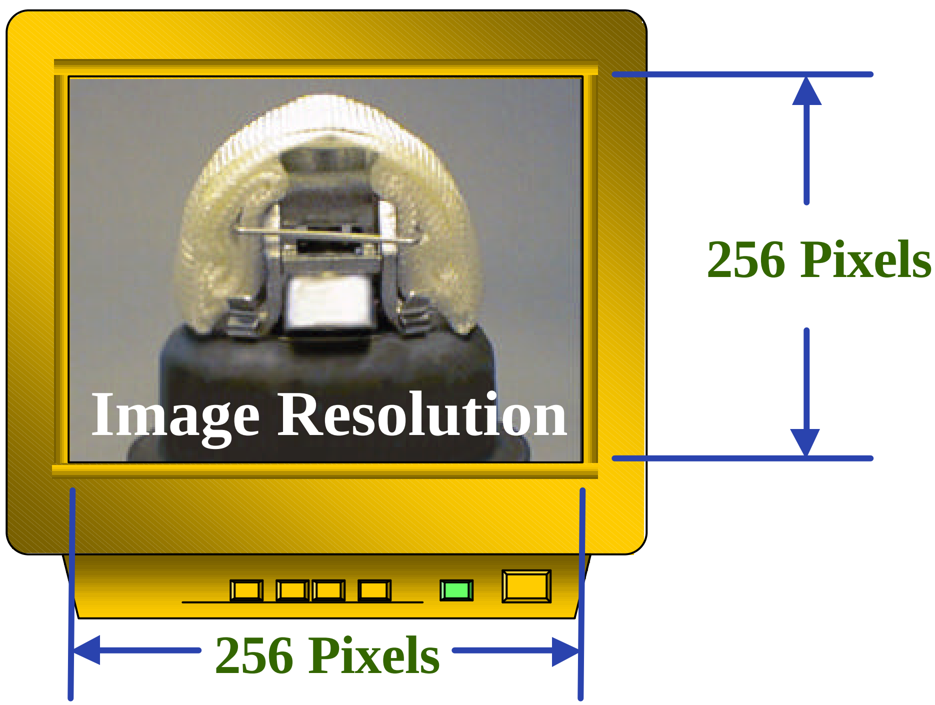
- Location
- Size
- Speed



Machine Vision Technology

PIXELS

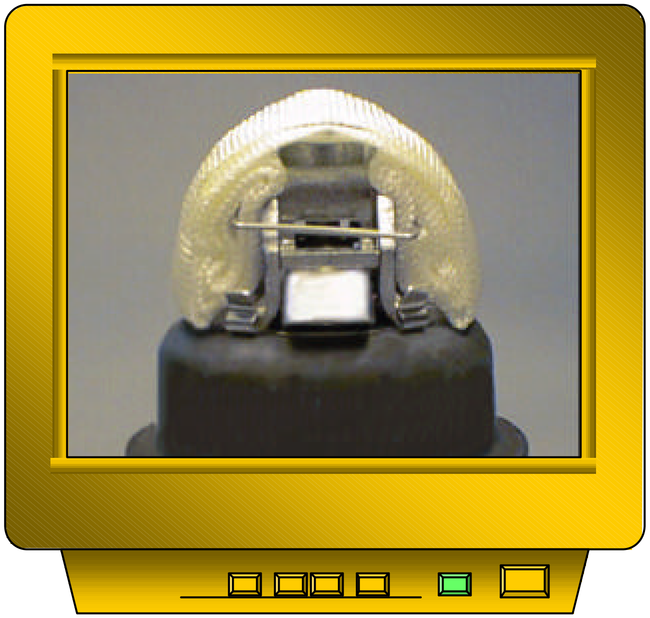
- PIcture + X + ELement



Machine Vision Technology

GRAY-SCALE IMAGE

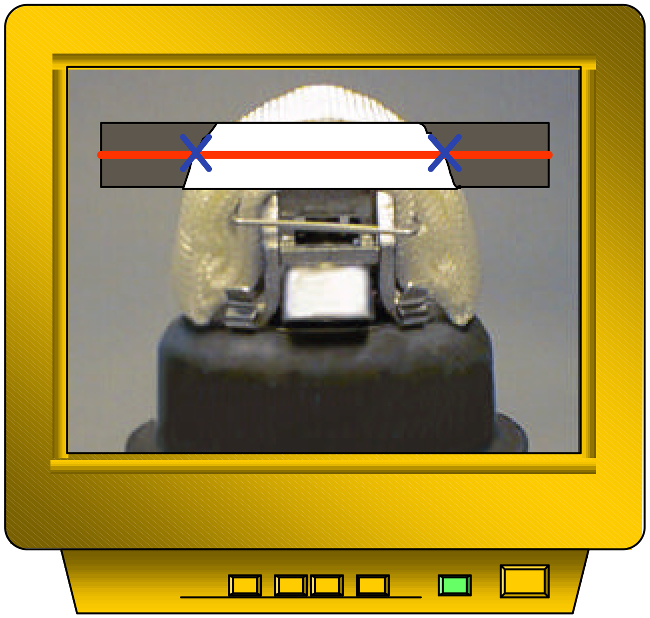
- **Digitized Screen Image**

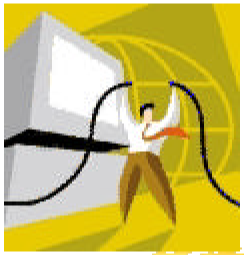


Machine Vision Technology

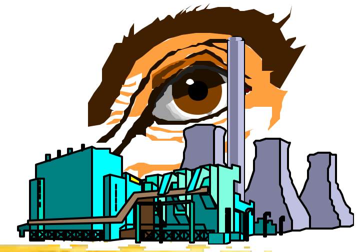
BINARY IMAGE

- Area Immediately Around Vision Tool



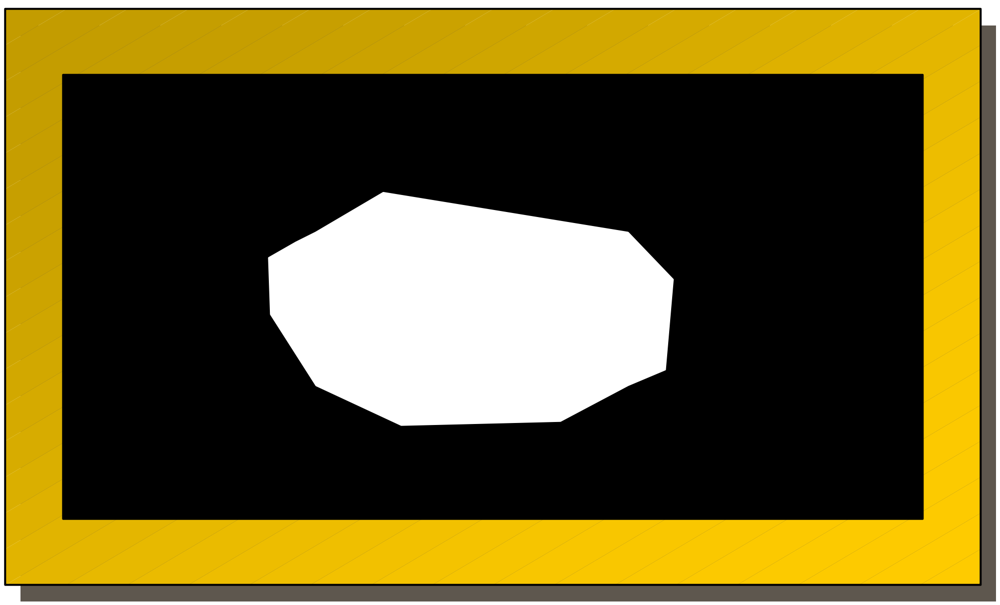


Machine Vision Technology



VISUAL NOISE

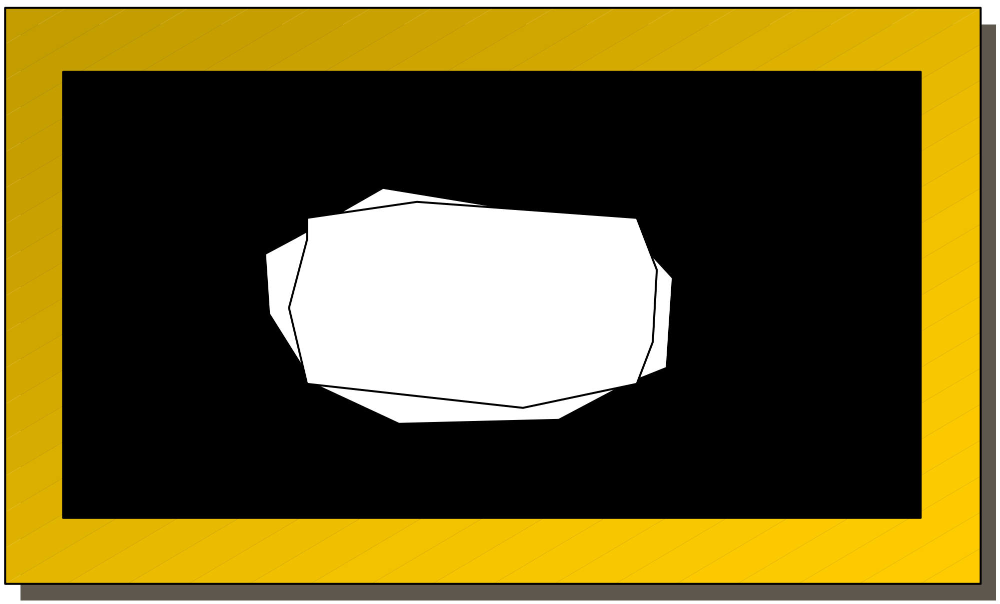
- **Unwanted White or Black Pixels**



Machine Vision Technology

FILTERING (MORPHING)

- Removes Unwanted Visual Noise

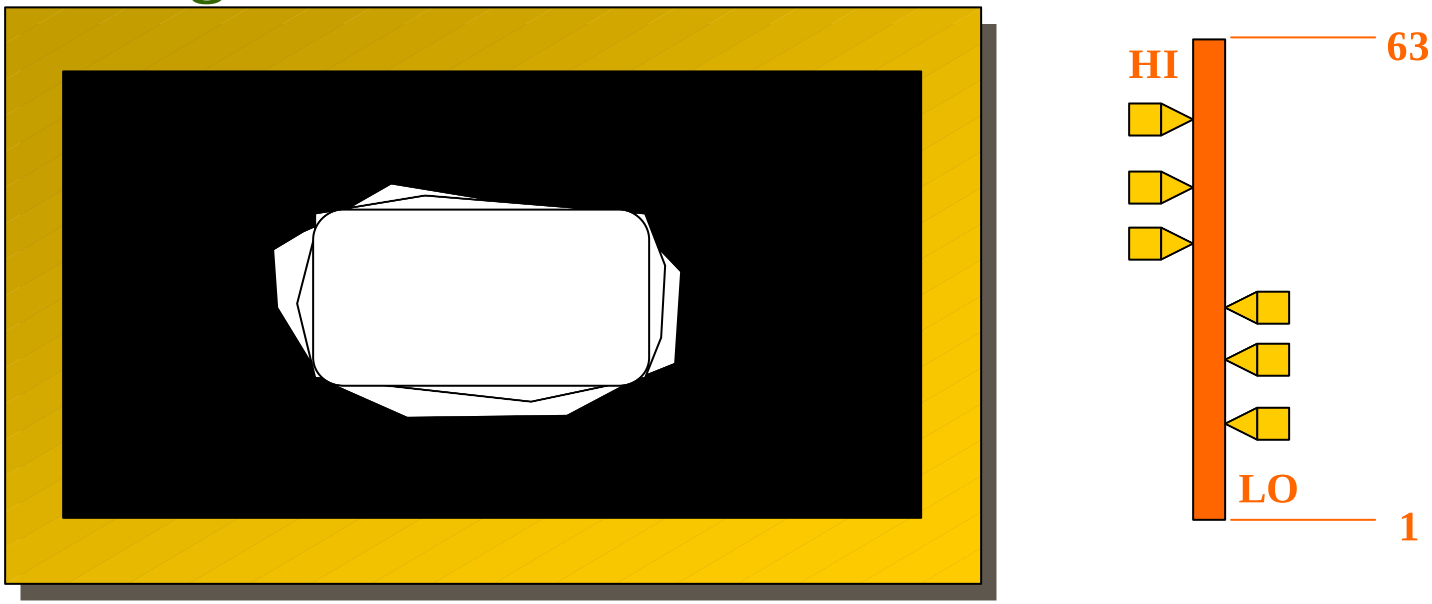


FILTER
White
0 Pixels
1 Pixels
2 Pixels
3 Pixels

Machine Vision Technology

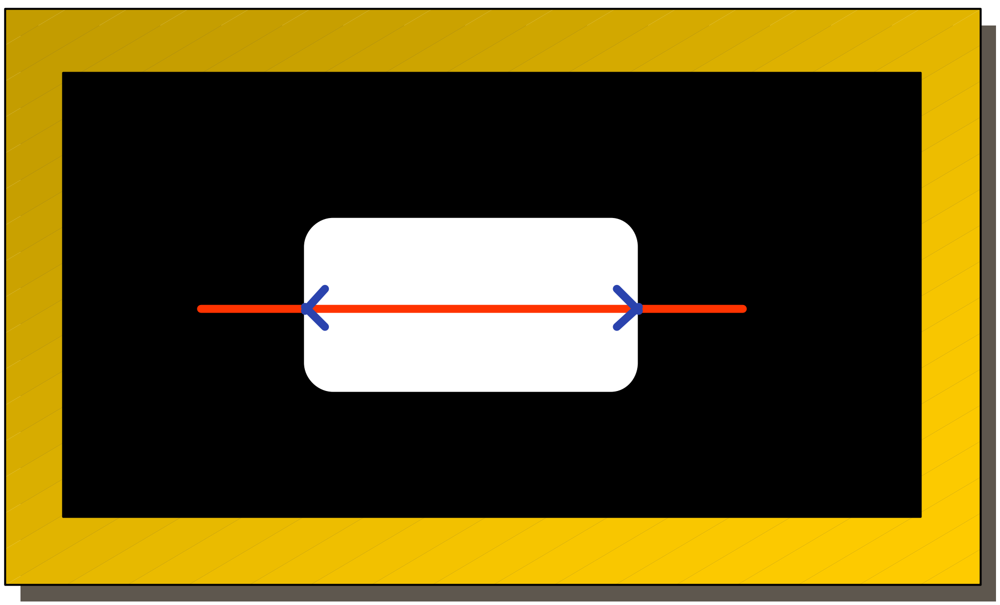
THRESHOLD

- Determines Which Part of Gray-Scale Image Becomes White or Black

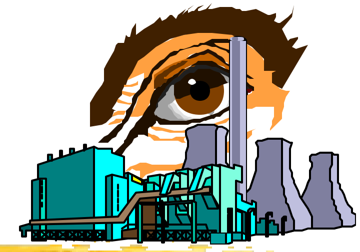


EDGES

- Black to White Transition Along Gage

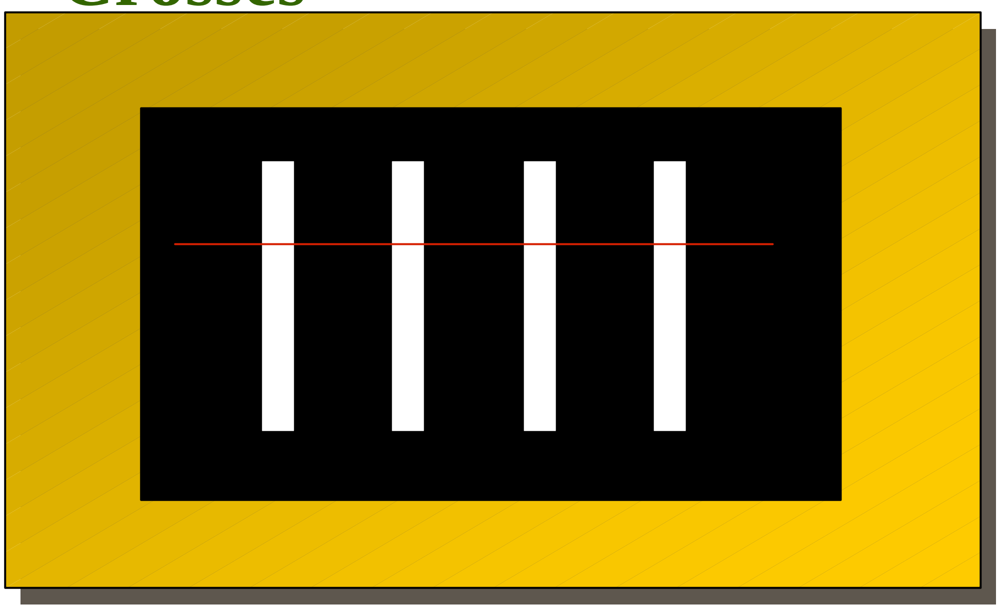


Machine Vision Inspection Tools



GAGES

- Inspects Specific Part of the Workpiece it Crosses

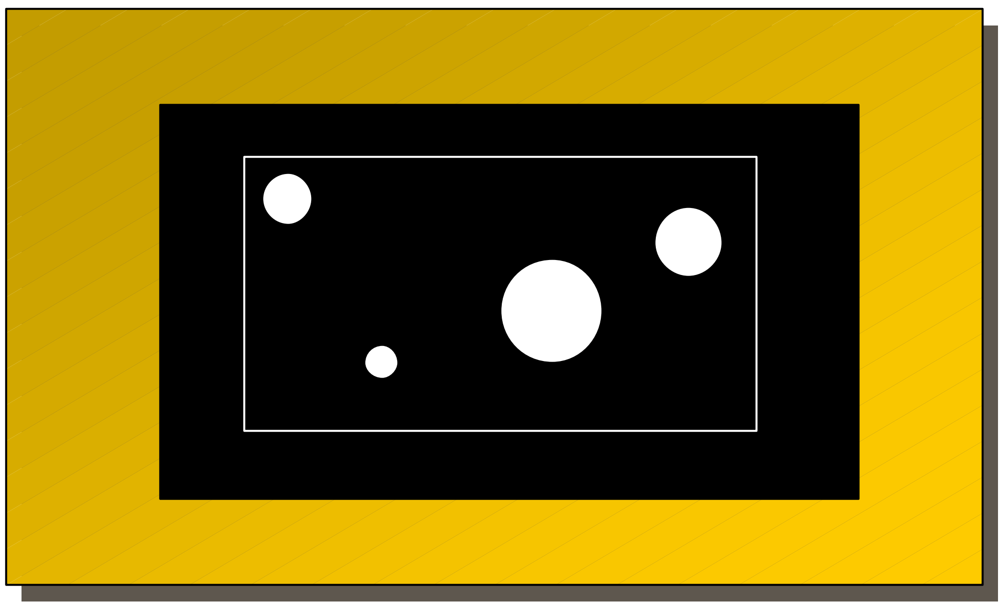


- Linear
- Circular

Machine Vision Inspection Tools

WINDOWS

- Count Pixels or Objects, Comparison

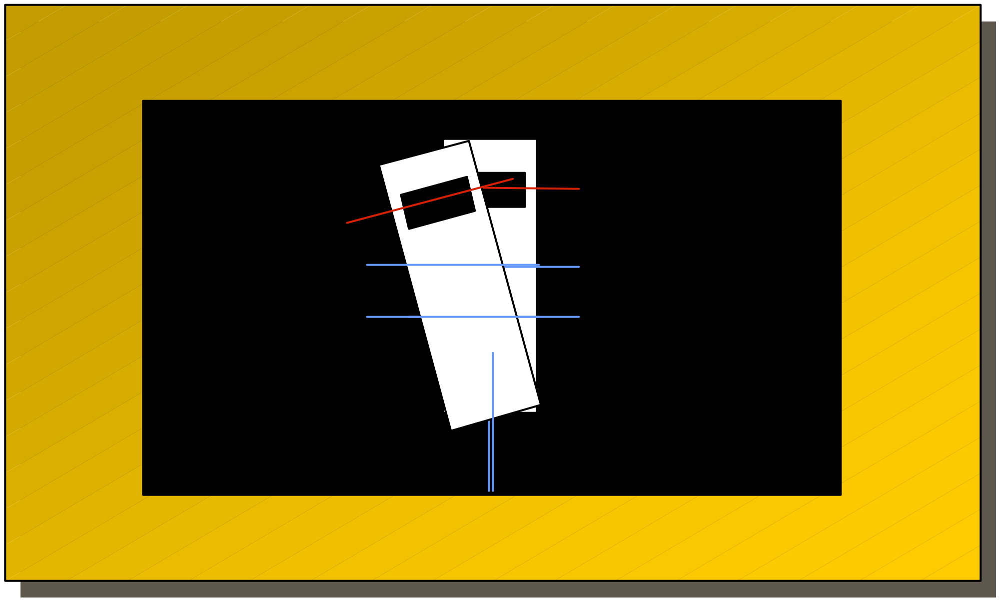


- Rectangular
- Circular
- Polygonal

Machine Vision Inspection Tools

REFERENCE LINES AND WINDOWS

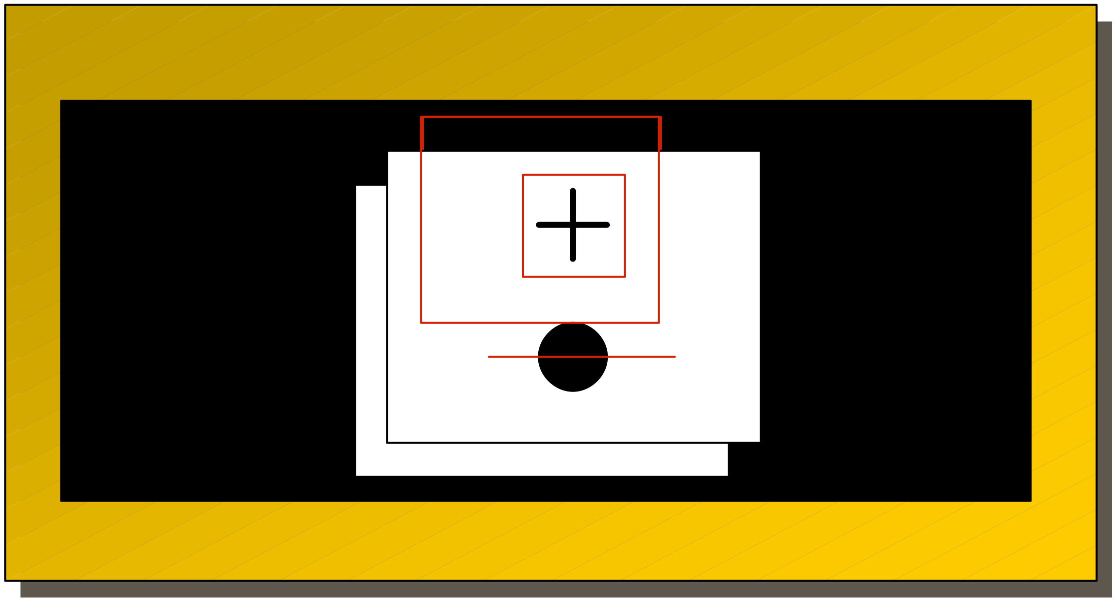
- Compensate for Shift or Rotation



Machine Vision Inspection Tools

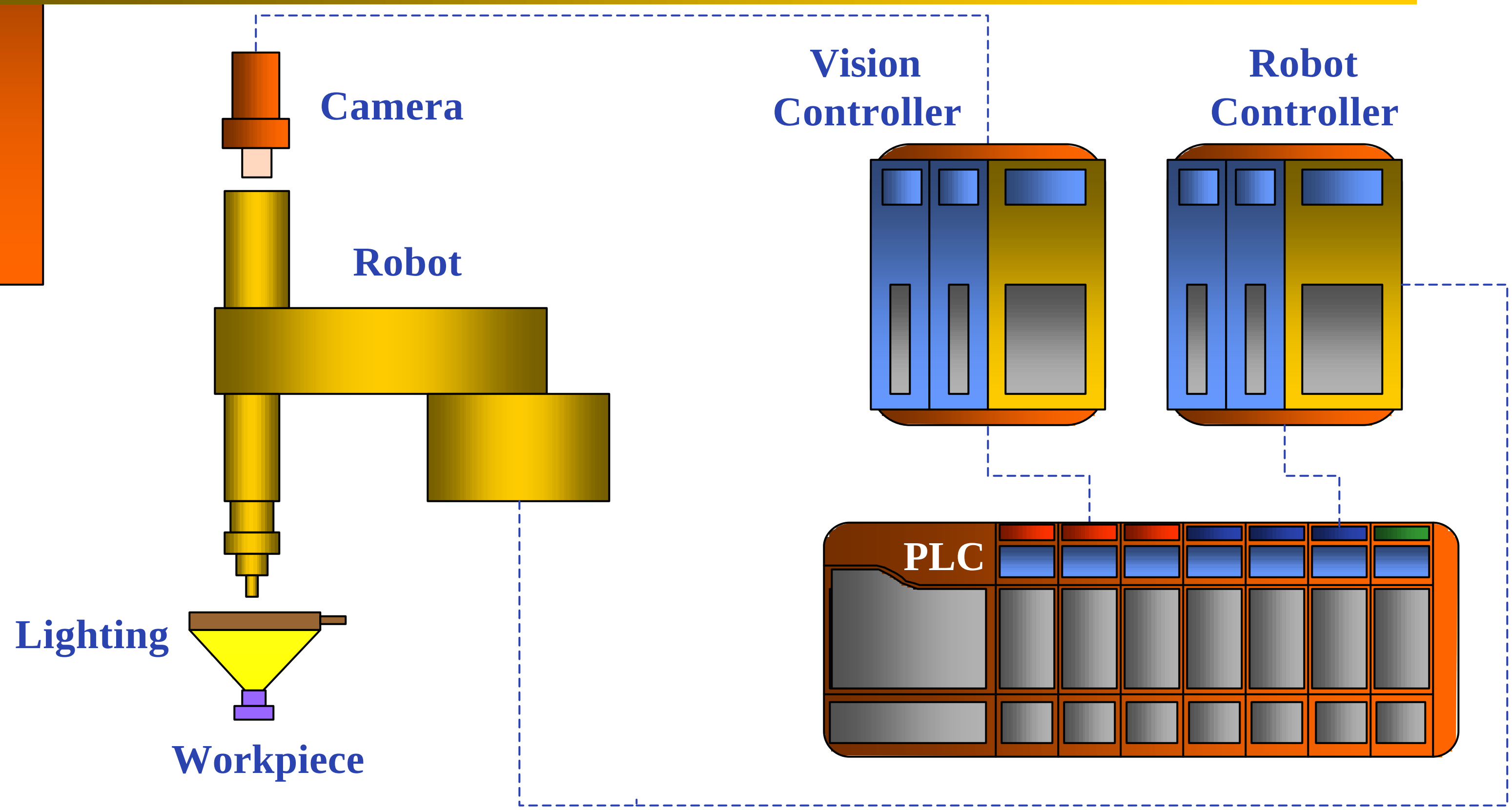
REFERENCE LINES AND WINDOWS

- Compensate for Shift or Rotation

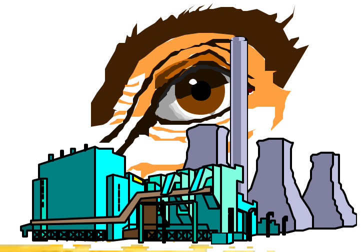


Machine Vision and LAP

PROCESS



Machine Vision and LAP

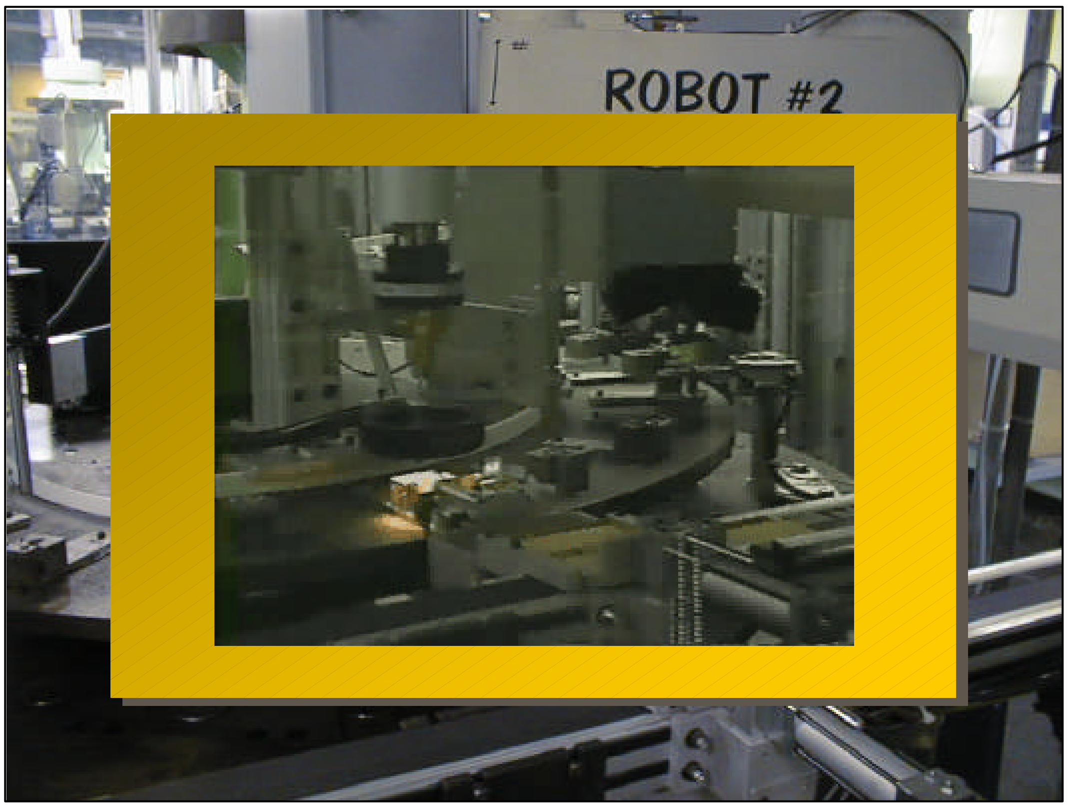


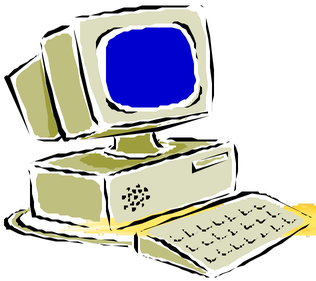
APPLICATIONS

- Orientation
- Assemble Components

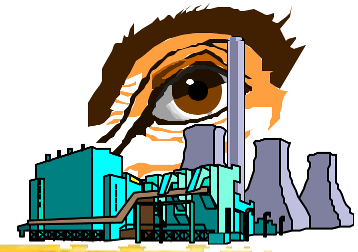
Machine Vision and LAP

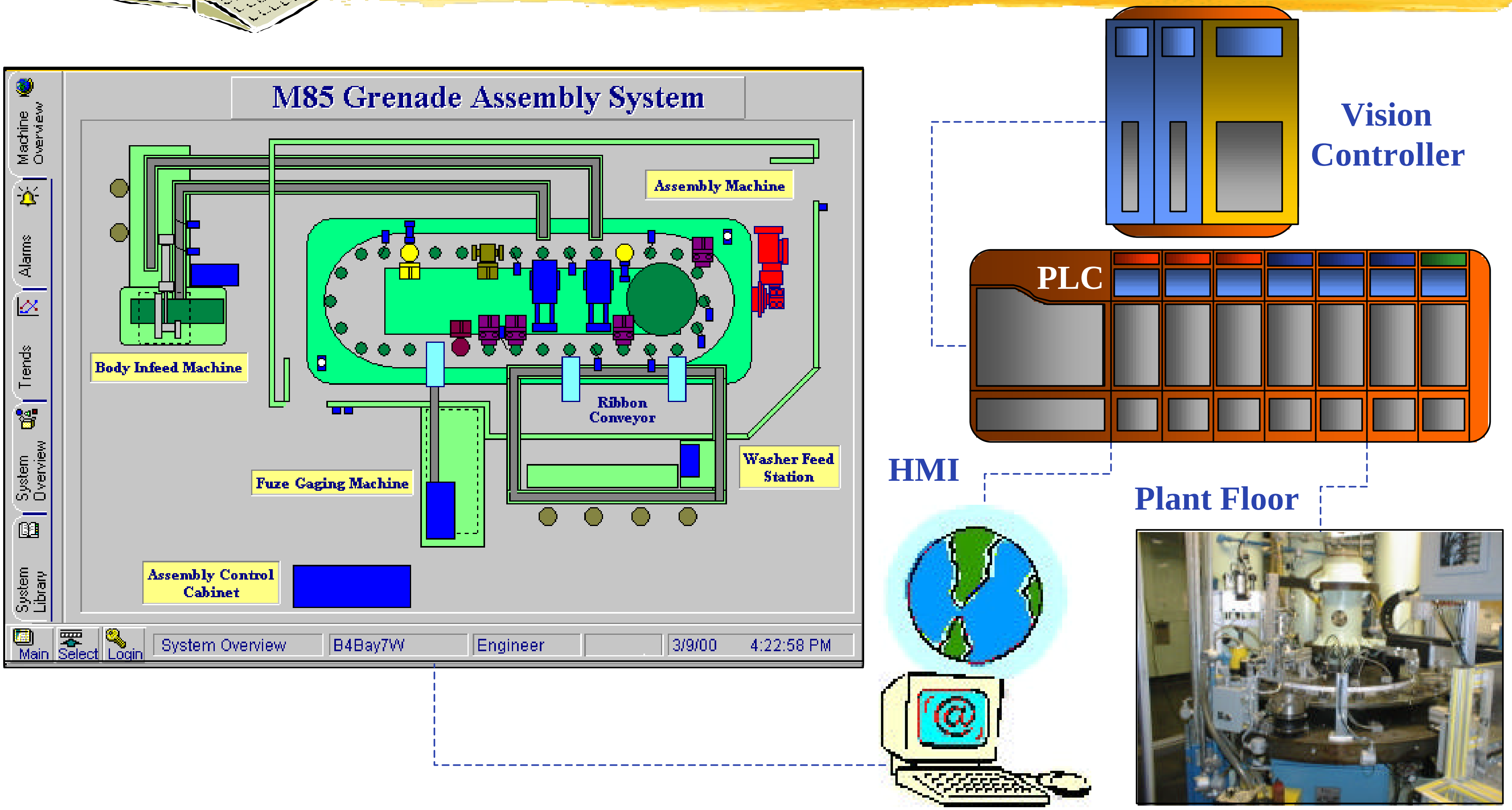
APPLICATIONS



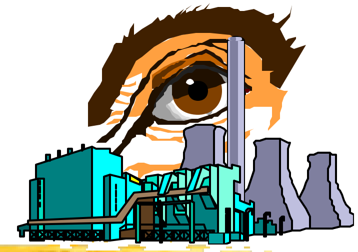


Human Machine Interface





Summary



- ☑ Machine Vision Still Evolving
- ☑ Machine Vision & Inspection
- ☑ Machine Vision & LAP
- ☑ Human Machine Interface

TACOM

Mobility and Firepower for America's Army

NATO STANDARDIZATION

AC310/SGII: FUZING AND OTHER INITIATION SYSTEMS

NDIA ANNUAL FUZE MEETING

11-12 APRIL 2000

FREDERICK R. TEPPER
TACOM-ARDEC FUZE DIVISION

OUTLINE

- **BACKGROUND**
- **STANDARDIZATION PRINCIPLES**
- **STATUS OF FUZE SYSTEM STANAGS**

BACKGROUND

- **NATO COLLABORATION AND JOINT OPERATIONS**
  - Identified potential problems in safety assessments
  - Interoperability
  - Purchase of foreign weapons
- **PROBLEMS FROM UNIQUE APPROACHES TO S3**
  - Testing
  - Assessment
- **AC310 PROVIDES FRAMEWORK FOR AGREEMENT**
  - Design Principles
  - Tests
  - Terminology
  - Environments

ESTABLISHMENT OF MUNITIONS GROUP

- **GROUP OF EXPERTS ON SAFETY ASPECTS OF STORAGE AND TRANSPORTATION OF AMMUNITION AND EXPLOSIVES**
  - Sub-Group of AC258 established 1978
  - Restructured as Group AC310

- **4 SUB-GROUPS FORMED AT FIRST MEETING DECEMBER 1979**

  SGI: Explosive Materials SGIII: Environment

  SGII: Fuzing Systems SGIV: Munition Systems

- **NAME CHANGED IN 1985:**

GROUP ON SAFETY AND SUITABILITY FOR SERVICE (S3) OF MUNITIONS AND EXPLOSIVES

NEED FOR S3 PRINCIPLES

- **CONSENSUS OF USERS AND DEVELOPERS**
  - Required for multinational use of munitions
  - S3 cannot be quantified precisely
  - Standards will define design requirements and provide detailed tests and methods
  - Allow verification by agreed Standards
- **DEVELOP SAFE FUZES USING NATIONS EXPERIENCE**
  - Produce, Transport, Handle, Store and Deploy

RESULT

- **PRINCIPLES DERIVED FROM EXPERIENCE**
- **STANAGs DEFINE GENERIC REQUIREMENTS**
  - Method of assessment
  - Testing
  - Environments
- **STANDARDS ALLOW INFORMED DECISIONS**
  - Well understood common test criteria
  - Uniform methods of assessment

DOCUMENTS

- **STANAG:** ***Standardizaton Agreement***

  Formal agreement by ratifying Nations defining the S3 assessment

- **AOP:** ***Allied Ordnance Publication***

  Guidance, general information, details of tests methods and processes to assess S3

GENERIC REQUIREMENTS

- **ASSESS S3 IN NORMAL / CREDIBLE ENVIRONMENTS**
  - Electromagnetic radiation
  - Sources of electrical, mechanical, thermal energy
  - Premature initiation of explosive train
  - After transport, handling, loading, and firing
- **EXPLOSIVE TRAIN**
  - Explosives qualified by STANAG 4170 (SGI)
  - Sensitive elements must be interrupted / out-of-line
  - In-line explosives with adequate safety margin
  - Munition must be safe to dispose (STANAG 4518)

SGII STANAGs/AOPs

STANAG/AOP	SUBJECT
ST 2916	Nose Fuze Contours /Interface (MIL-STD-333)
ST 4157/AOP-20	Qualification Tests (MIL-STD-331)
ST 4187/AOP-16	Design Req'ts (MIL-STD-1316)
ST 4363/AOP-21	Testing of Leads and Boosters
ST 4368	Electric and Laser Ignition Systems for Missile and Rocket Motors (MIL-STD-1901)

SGII STANAGs/AOPs

STANAG/AOP	SUBJECT
ST 4326/AOP-8	NATO Fuze Catalog
ST 4369/AOP-22	Inductive Setting: Large Cal
ST 4547	Inductive Setting: Med Cal
ST 4560	Initiators

CURRENT STATUS

STANAG	STATUS
• **2916**	**Promulgated. New edition to be developed as required.**
• **4157/Ed.1**	**Promulgated**
4157/Ed.2	***Final Draft in ratification process***
• **4187/Ed.1, 4187/Ed.2**	**Promulgated**
4187/Ed.3	***Final Draft in ratification process***
4187/Ed.4	***In process in SGII***
• **4326**	**Promulgated**
4326/Ed.2	***In process in SG II***

CURRENT STATUS

STANAG	STATUS
• 4363/Ed.1	**Promulgated**
4363/Ed.2	***Final Draft in ratification process***
4363/Ed.3	***In process in SGII***
• 4368/Ed.1	**Promulgated**
4368/Ed.2	***Final Draft in ratification process***
4368/Ed.3	***To be initiated***
• 4369/Ed.1	**Promulgated**
• 4547	***New draft under preparation in SGII***
• 4560	***New draft under preparation in SGII***

STANAG 2916

NOSE FUZE CONTOURS AND MATCHING CAVITIES FOR ARTILLERY AND MORTAR PROJECTILES

- **Derived from MIL-STD-333**
- **New contours developed will require a new edition**

STANAG 4157 AND AOP-20

FUZING SYSTEMS: TESTING REQUIREMENTS FOR ASSESSMENT OF SAFETY AND SUITABILITY FOR SERVICE

- **Derived from MIL-STD-331**
- **Ratification of STANAG 4157/Ed.2 is underway**
- **Mortar Double Loading Test will be Addendum to AOP-20**

The US FESWG and SGII agreed to maintain consistency between MIL-STD-331 and AOP-20. Notes are added for NATO users.

STANAG 4187 AND AOP-16

FUZING SYSTEMS - SAFETY DESIGN REQUIREMENTS

- **Derived from MIL-STD-1316**
- **Ratification of Ed. 3 is underway**
- **Topics for Edition 4 include smart mines, ESADs, and formal safety analyses**

STANAG 4326 AND AOP-8

NATO FUZE CHARACTERISTICS DATA

- **Catalog providing brief description with sketch of NATO Fuzes**
- **Includes information such as**
  - **dimensions**
  - **interface**
  - **NATO Stock Num**
  - **Dwg Num**
  - **major components**
  - **performance levels**
  - **explosive characteristics**
- **Provides description of operation**
- **Next edition in CD ROM format**

STANAG 4363 AND AOP-21

FUZING SYSTEMS: DEVELOPMENT TESTING FOR THE ASSESSMENT OF LEAD AND BOOSTER EXPLOSIVE COMPONENTS

- **Ed. 2 has entered ratification process**
- **Detonating Cord Water Gap test issues will be resolved for Ed.3**

STANAG 4368

ELECTRIC AND LASER IGNITION SYSTEMS FOR ROCKETS AND GUIDED MISSILE MOTORS -- SAFETY DESIGN REQUIREMENTS

- **Ed. 2 has entered ratification process**
- **Initiation of work on Ed. 3 to include requirements for low voltage laser initiation devices will be considered at next SGII meeting**

STANAG 4369 and AOP-22

DESIGN REQUIREMENTS FOR INDUCTIVE SETTING OF LARGE CALIBER PROJECTILE FUZES

- **Edition 1 has been promulgated**
- **Need for new edition to be discussed at next meeting of SGII**

STANAG 4547 (DRAFT)

DESIGN REQUIREMENTS FOR INDUCTIVE SETTING OF MEDIUM CALIBER PROJECTILE FUZES

- **A new draft of this new STANAG is in process**
- **Draft expected for next meeting of SGII**

STANAG 4560

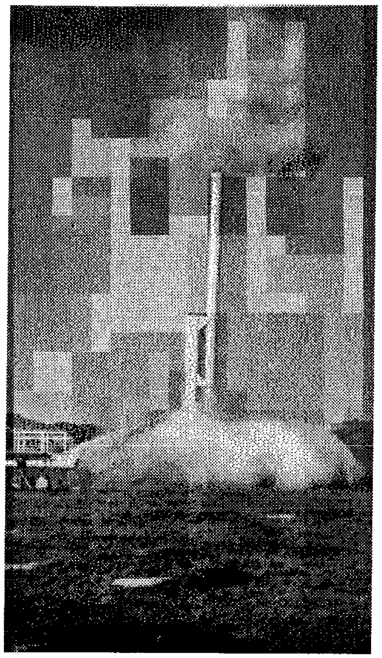
ELECTRO-EXPLOSIVE DEVICE, ASSESSMENT AND TEST METHODS FOR CHARACTERIZATION

- **This is proposed title for new STANAG.**
- **Initially will be limited to EBW's and EFI's**
- **Existing National Tests will be referenced**
- **New draft is in process**

SUMMARY

- **Enable interoperability**
- **Facilitate procurement of Foreign munitions and weapons**
- **STANAGs assure adequate assessment for Safety and Suitability for Service**

CHALLENGES AND SOLUTIONS IN ACCELEROMETER BASED FUZING OF SMART WEAPONS



Patrick L. Walter

Current: Senior Technologist/E
Current: Senior Design Lecturer/**TCU**
Former: Manager Sandia National Labs

44TH Annual Meeting of the Fuze Section
Munitions Technology Division
National Defense Industrial Association

TCU

Sandia National Laboratories

E

PRESENTATION GOALS

1. Summarize accelerometer design lessons that transfer from 30 years experience in high-shock measurements associated with nuclear effects testing.

2. Briefly discuss:
   - trends in accelerometer mounting and differences in demands placed on accelerometer performance dependent upon whether the acceleration signal, its 1st integral (velocity), or its 2nd integral (displacement) is used in the fusing logic, and
   - a previously developed mechanical packaging scheme that could enhance penetrator fuse performance.

TCU

E

BACKGROUND

- For more than 30 years nuclear effects testing of structures has required high shock measurements.
- The commonality of these measurements with smart fuzing of penetrating weapon systems includes:
  - shock environments to 10's of thousands of g's can be experienced and
  - excitation forces to the structure can contain very high frequencies.

TCU

E

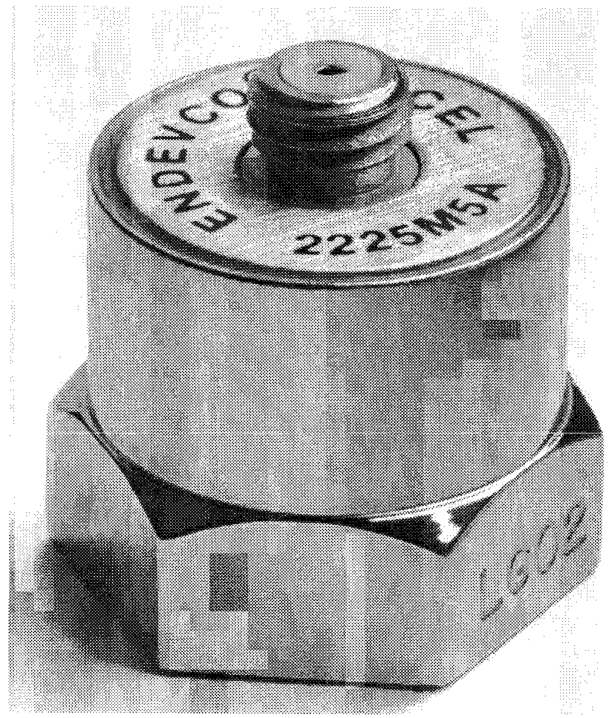
BACKGROUND

- The differences include: (1) less requirements for acceleration signal integration and (2) less kinetic energy associated with the system structural loading.
  - Note: Prior nuclear weapons testing has required the instrumentation of high energy projectiles such as 155 mm artillery shells and earth penetrators.

TCU

E

ACCELEROMETER DESIGN LESSONS: (1965) 1st ADVERTISED +/- 100,000 G ACCELEROMETER



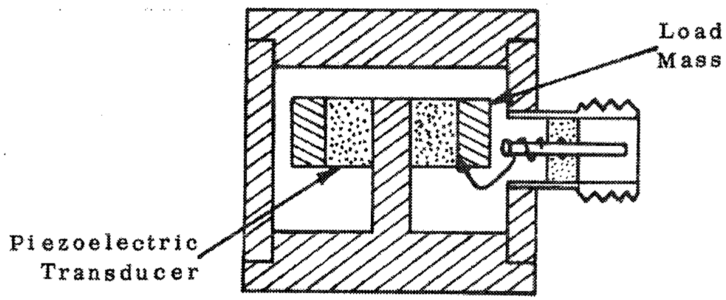
Endevco 2225M5:
Above is later version, but w. same geometry.

Transduction basis is ferroelectric ceramic material in annular shear.

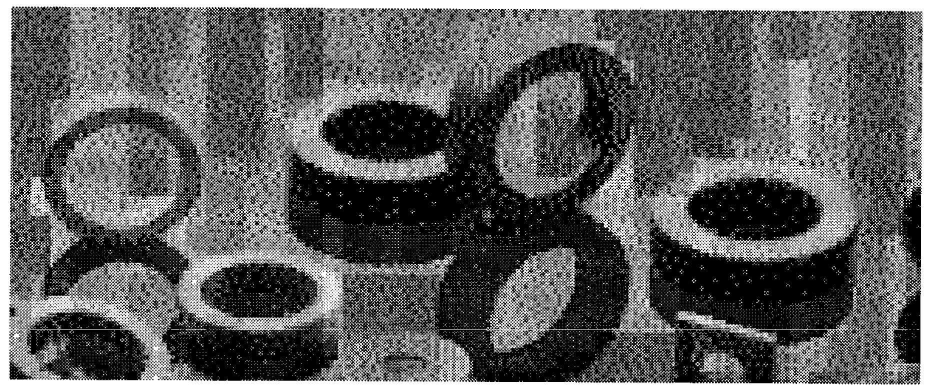
TCU

E

ACCELEROMETER DESIGN LESSONS: REPRESENTATIVE TRANSDUCTION ELEMENTS



Simple accelerometer pictorial



Ferroelectric ceramics

Typical annular shear ferroelectric accelerometer and various elements are shown.

ACCELEROMETER DESIGN LESSONS: FERROELECTRIC ELEMENT DEFINED

- Piezoelectric: No center of charge symmetry (21 of 32 crystal classes lack this symmetry, 20 are piezoelectric). Stress results in an electrical charge output. (e.g.,quartz)

- Pyroelectric: Subset of piezoelectric (10 crystal classes have a dipole in their unit cell, thermal heating results in an electrical charge output). (e.g.,tourmaline)

TCU

E

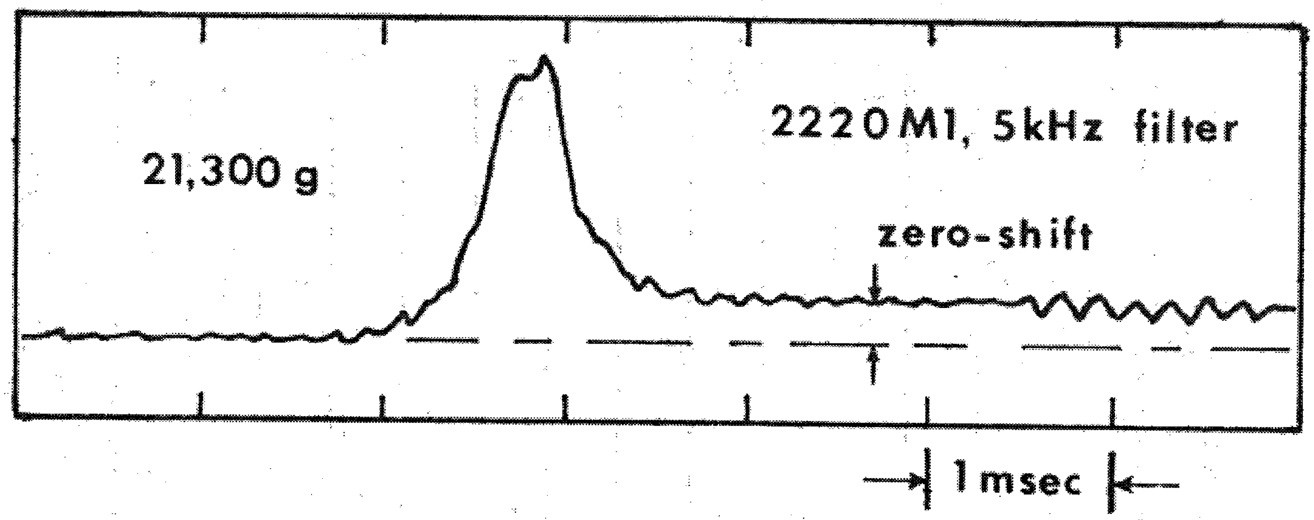
ACCELEROMETER DESIGN LESSONS: FERROELECTRIC ELEMENT DEFINED

- Ferroelectric: Subset of pyroelectric. Dipoles are in domains. Possess spontaneous polarization that can be reversed by suitable electric field (switching accompanied by hysteresis). (e.g., rochelle salt)

- Ferroelectric Ceramic: Polycrystalline ceramic mass that can be pressed, fired, electroded, and poled by a high electric field resulting in piezoelectric properties. (e.g., barium titanate, lead zirconate titanate)

TCU

ACCELEROMETER DESIGN LESSONS: *FERROELECTRIC CERAMICS CAN ZERO-SHIFT!!!*



Ferroelectric ceramic accelerometer has zero-shifted.

ACCELERATOR DESIGN LESSONS: *FERROELECTRIC CERAMICS CAN ZERO-SHIFT!!!*

- Many reasons for zeroshift of these ferroceramic accelerometers exist *(Chu, Anthony, Zeroshift of Piezoelectric Accelerometers in Pyroshock Measurements, 57th Shock and Vibration Symposium, Naval Research Laboratory, Shock and Vibration Information Center, January 1987.)*
  - physical movement of sensor parts,
  - cable noise,
  - base strain,
  - inadequate low frequency response,
  - overloading of the signal conditioning, and
  - overstress of their sensing elements. *(Plumlee, 1971)*

TCU

E

ACCELEROMETER DESIGN LESSONS: (EARLY 1970S) *UNDERSTANDING OF OVERSTRESS MECHANISM OF ZERO-SHIFT!!!*

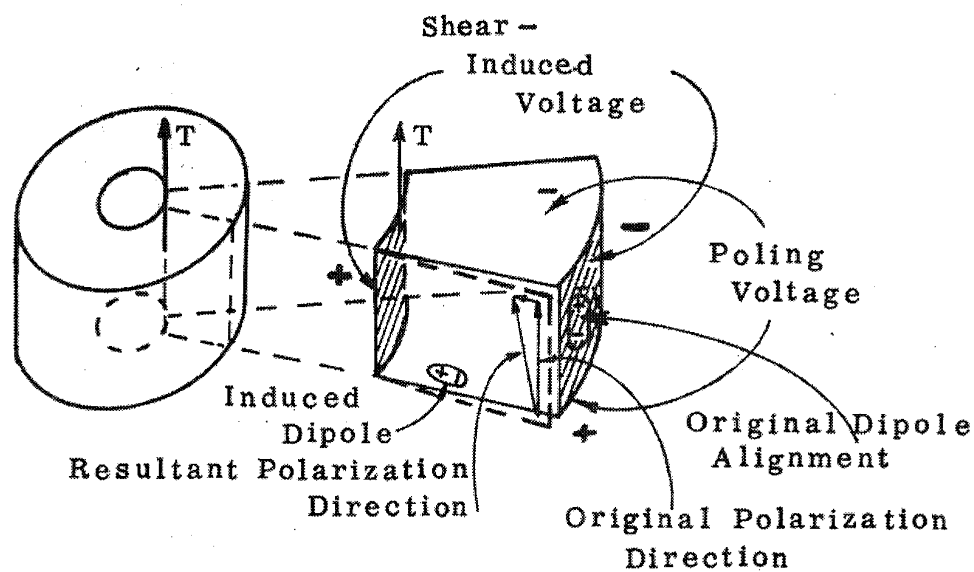
- Physical mechanism: Ferroelectric ceramics are capable of stresses to 10's of thousands of psi. At stresses below 100 psi (more typical accelerometer operating range), polarization reorientation of the ferroelectric ceramics can occur. A zero shift of 10-20% of the accelerometers peak response may correspond to a change in the ceramic's permanent polarization of only 0.01%. *The accelerometer would remain stable and recalibrate fine.*

Ralph H. Plumlee, ZERO-SHIFT IN PIEZOELECTRIC ACCELEROMETERS (Polarization Switching in Polycrystalline Ferroelectrics at Very Low Fields and Stresses), Sandia Laboratories SC-RR-70-755, March 1971.

TCU

E

ACCELEROMETER DESIGN LESSONS:
FERROELECTRIC CERAMICS CAN ZERO-SHIFT!!!

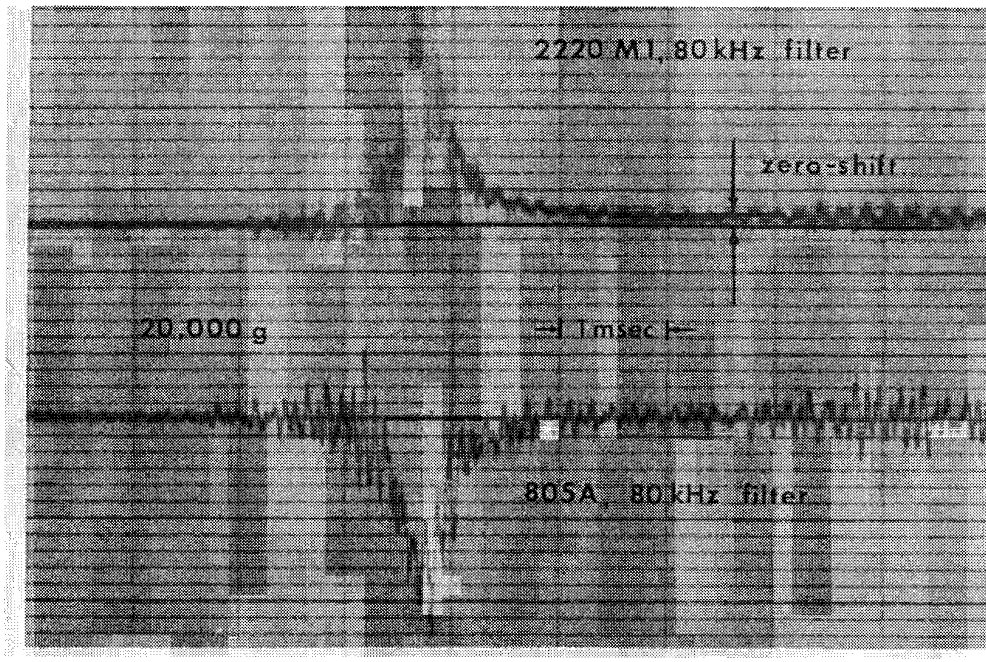


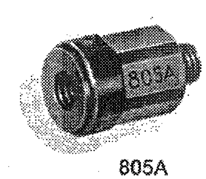
Pictorial example of overstress cause that remains a limitation in ferroelectric ceramics.

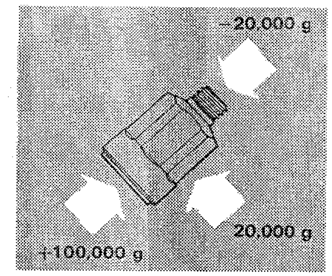
TCU

E

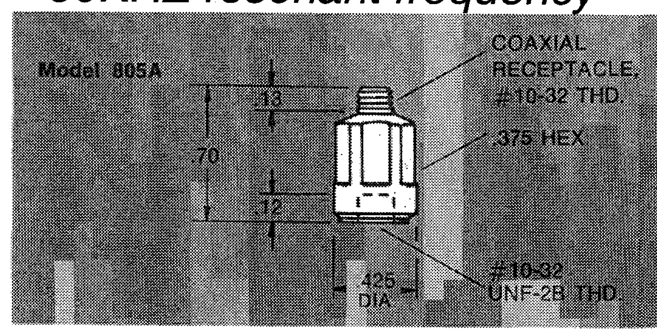
ACCELEROMETER DESIGN LESSONS:
FERROELECTRIC CERAMICS CAN ZERO-SHIFT!!!







60KHZ resonant frequency

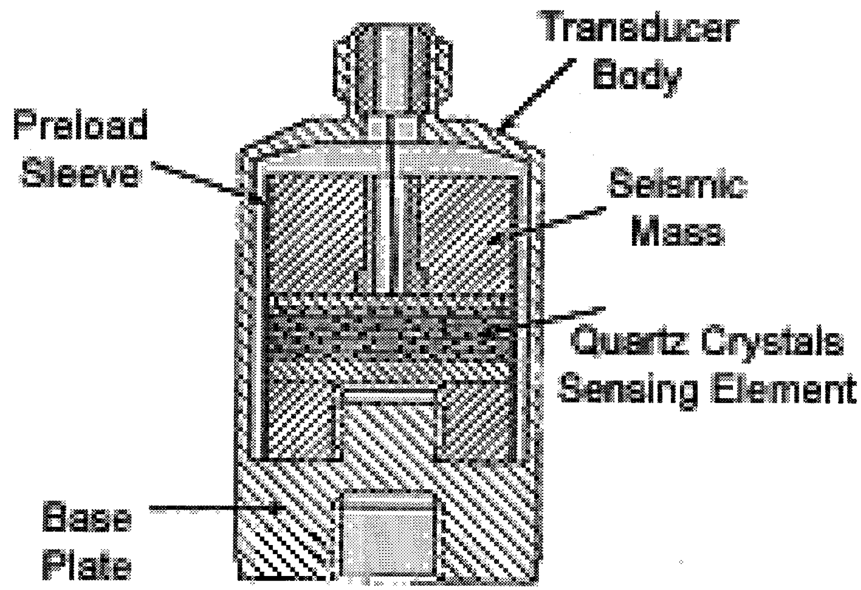


Quartz accelerometers should be immune to zero-shift due to overstress [Kistler 805A (introduced 1966) became workhorse early 1970s].

TCU

E

ACCELEROMETER DESIGN LESSONS:

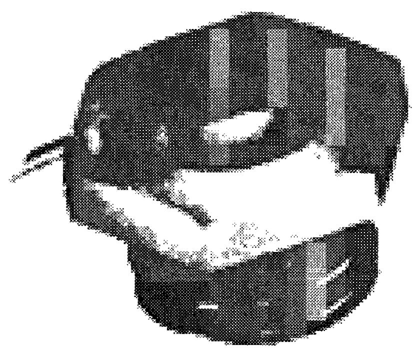


But quartz crystals are stacked and preloaded and succumb to relative motion, resulting in zero-shift for their own unique reasons in high shock environments.

TCU

E

ACCELEROMETER DESIGN LESSONS: (1969)



3 grams/250,000 Hz resonance

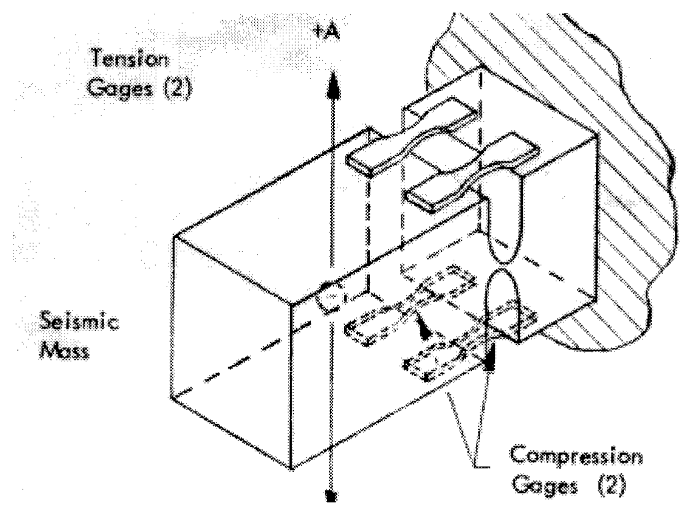
Endevco designed the Model 2291 in a reverse shear mode in 1969 to minimize stress loading. Base strain sensitivity overcame any design advantages.

TCU

E

ACCELEROMETER DESIGN LESSONS: SILICON BECOMES AN ALTERNATIVE TRANSDUCTION TECHNOLOGY

- 1961 Endevco establishes Solid State Accelerometer Laboratory
- 1966 10,000 G bulk silicon gage piezoresistive accelerometer available
- 1967 radiation hardened diffused semiconductor gages available

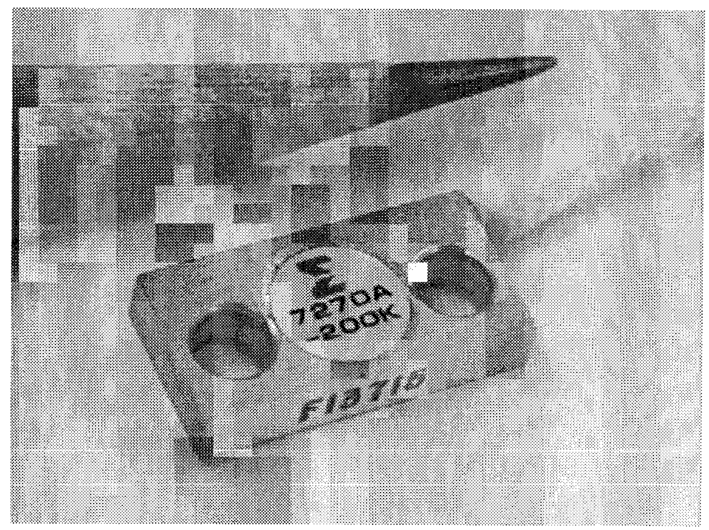


TCU

E

ACCELEROMETER DESIGN LESSONS: SILICON BECOMES AN ALTERNATIVE TRANSDUCTION TECHNOLOGY

- 1968 nonradiation hardened accelerometers available to 20,000 Gs
- 1974 studies performed for 100,000 G sculptured silicon MEMS accelerometer available
- 1983 Model 7270 became available in ranges to 200,000 G with resonant frequencies to 1,200,000 Hz



TCU

E

TACOM

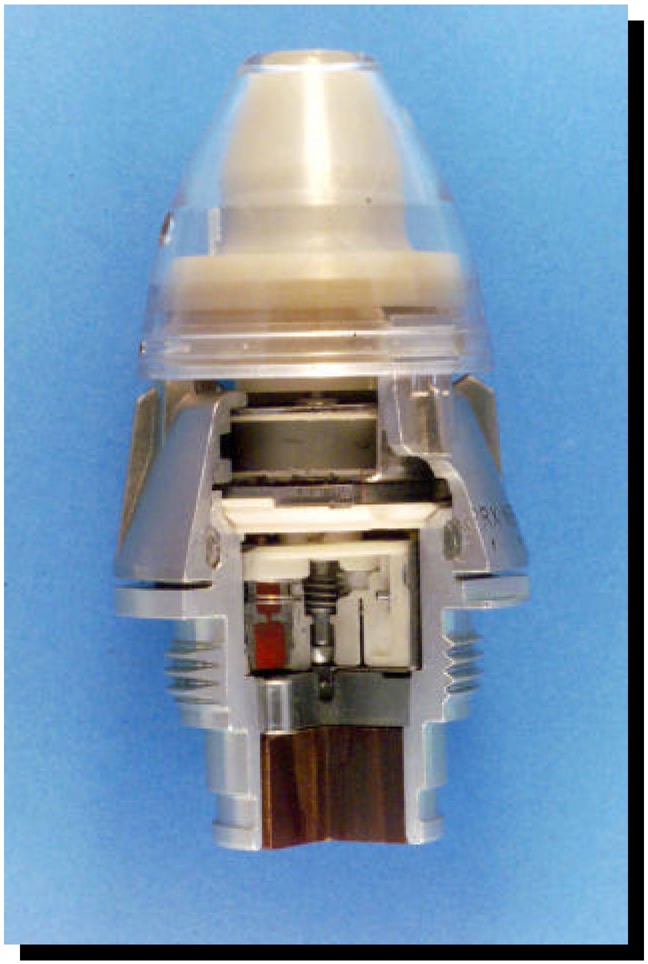
Mobility and Firepower
for America's Army

NDIA
44th Annual Fuze Conference

Experimental Characterization
Of M745 Explosive Train
April 12, 2000

Dennis W. Ward
TACOM-ARDEC Fuze Division

M745 PD Fuze



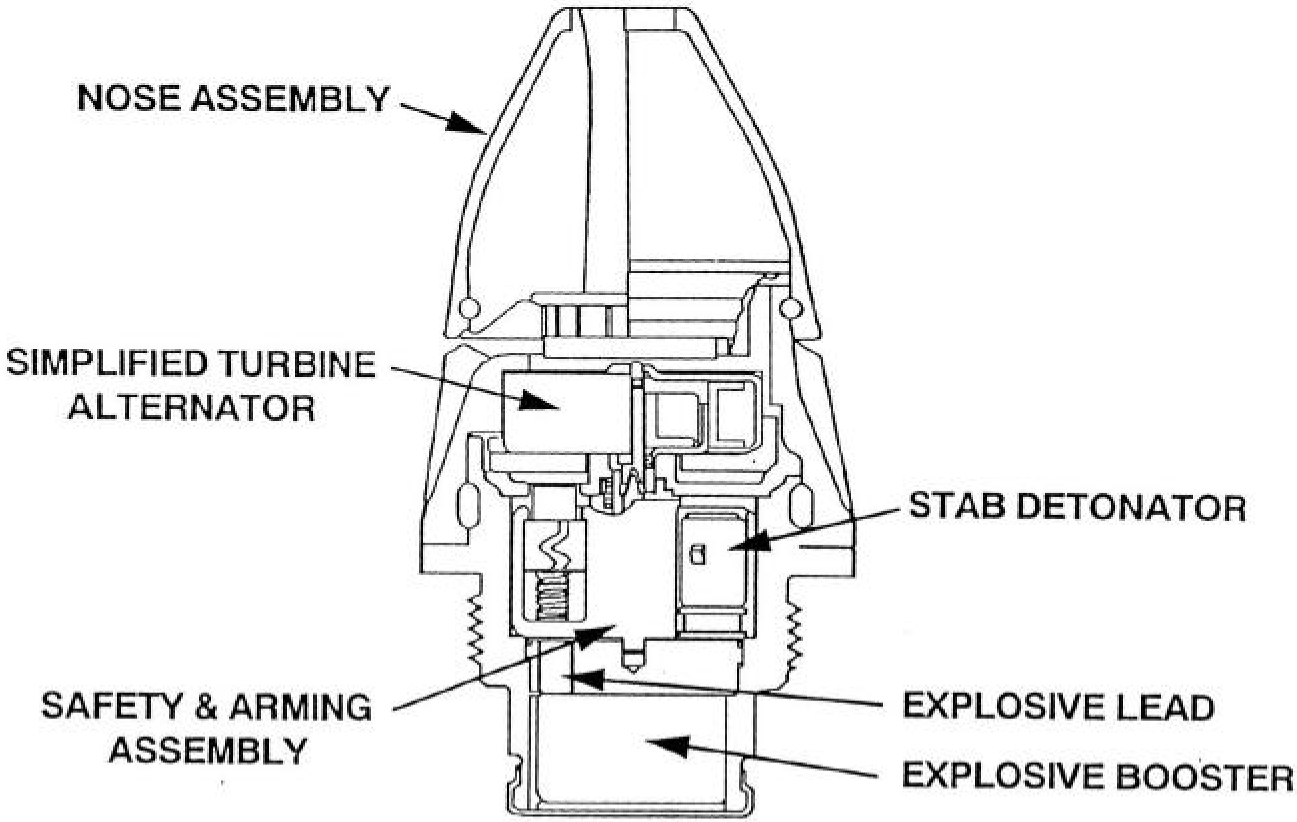
- Since 1985 the M745 has had occasional duds attributed to malfunctioning of the lead and/or booster
- Recently experienced 27 duds during 120mm smoke cartridge BLAT
- The large quantity of duds in a single test prompted a failure analysis
- As a result of this investigation we discovered a number of interesting results

Participants

Fuze Division	- Adelphi, Dover
Energetics and Warheads	- M. Joyce, D. Aaron
PA & TD	- K. Ng
Army Fuze Mgmt Office	- R. Johnson
PM-MO	- N. Friedman
Engineering Support, RI	- K. McMahon
NSWC @ White Oak	- S. Nesbitt, L. Montesi
ATK - Accudyne Operations	- R. Frazier

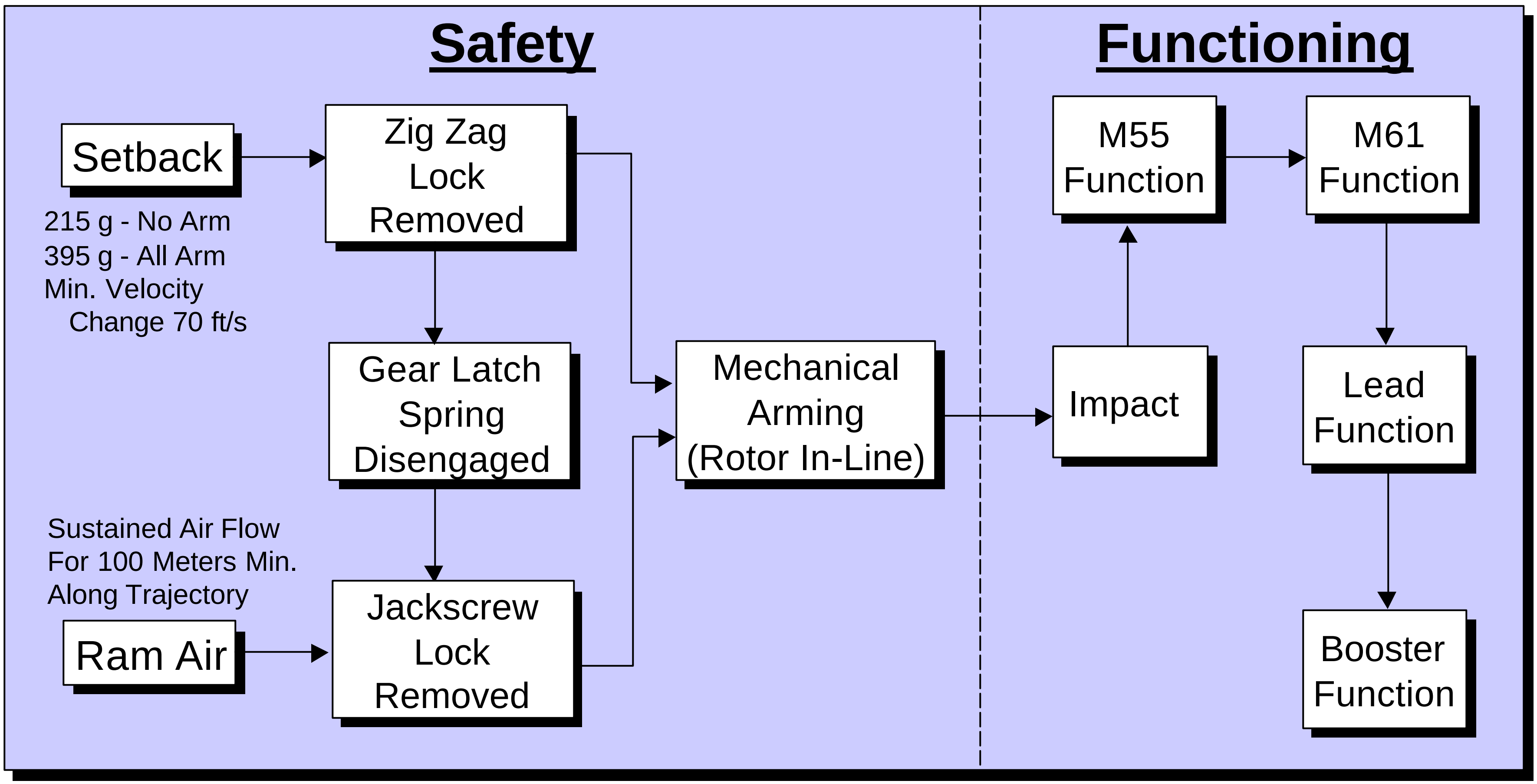
Committed to Excellence

M745 Fuze
Major Assemblies



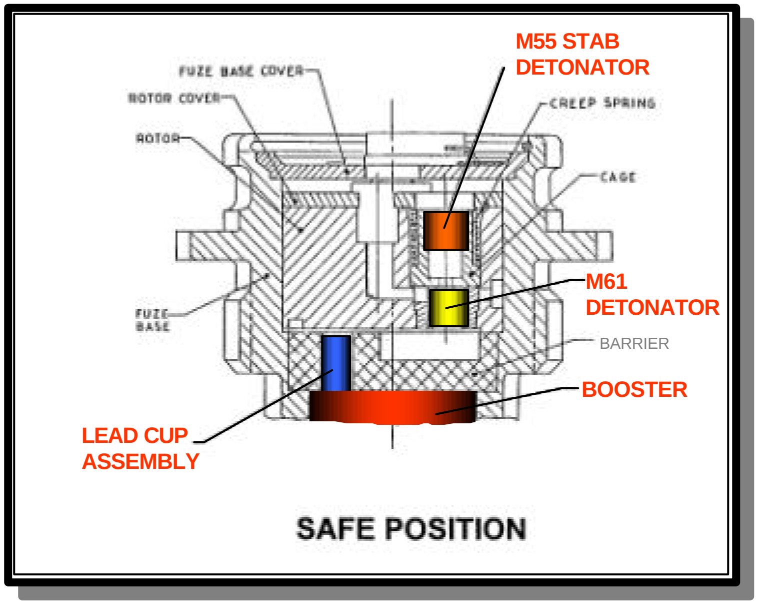
Committed to Excellence

M745 System Block Diagram

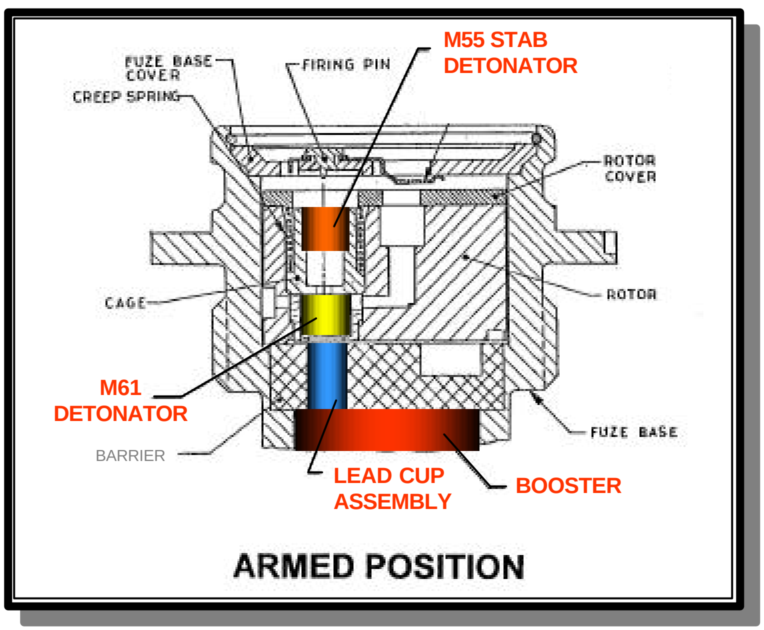


Committed to Excellence

M745 Explosive Components



SAFE POSITION



ARMED POSITION

M55 Stab Detonator - 85 mg

NOL 130 Primer Mix	15 mg (apx)
Lead Azide, RD1333	51 mg (apx)
RDX	19 mg (apx)

M61 Stab Detonator - 153 mg

NOL 130 Primer Mix	40 mg (min)
Lead Azide, RD1333	80 mg (min)
RDX	33 mg (apx)

Lead Charge - PBXN-5, 125 mg

Booster - Comp. A-5, 8 grams

Cause of Investigation

(Summary of M745 Duds from M929 BLAT's @ YPG)

Failure Mode	No. of Duds	Comments
• S&A's Armed • Primary Explosives Functioned • Non-functioning or improper functioning of lead charge	12	9 at Charge 0 3 at Charge 1
• Non-function of Primary Explosives (Sensitivity Duds) or Non-armed S&A	3	Duds due to limitations of current impact system for glancing impacts or rotor "glued" in place by silicone applied to booster pellet.

- M745 Experience 27 duds in 6 lots of smoke round BLAT's
- 15 recovered and disassembled
- 12 attributed to improper or non-functioning of lead charge
- Remaining attributed to other fuze duds

M745 Historical Performance Data

M745 (# Duds/Total)

Fuze BLAT (108 ea.)

Chg 0	54 / 1582	(3.41%)
Chg 1	7 / 270	(2.59%)
Chg 4	10 / 1584	(0.63%)
	71 / 3436	(2.07%)

M929 (# Duds/Total)

120mm Cartridge BLAT

Chg 0	23 / 293	(7.85%)
Chg 1	4 / 129	(3.10%)
Chg 4	6 / 317	(1.89%)
	33 / 739	(4.46%)

Possible Contributing Factors for the Failures

- Lead density, compression load, confinement
- Moisture content
- Explosive composition (M61 and Lead)
- Partially armed rotor
- Missing lead
- Missing output disk on M61
- Missing pressed increment in lead
- Detonator installed upside down

Testing and Results

- Ballistic Tests (To repeat failure conditions and eliminate specific lead lots)
- Lead Radial Confinement
- Inverted M61 Detonator
- Penalty Gap (M61/Lead)
- Interface Tests (M55/M61 and M61/Lead)
- Lead Density Tests (High and Low)

All testing indicated that the lead was **NOT** the cause of the failures

- M61 Output Tests (in cages and bare)

M61 Characteristics
Tests and Results

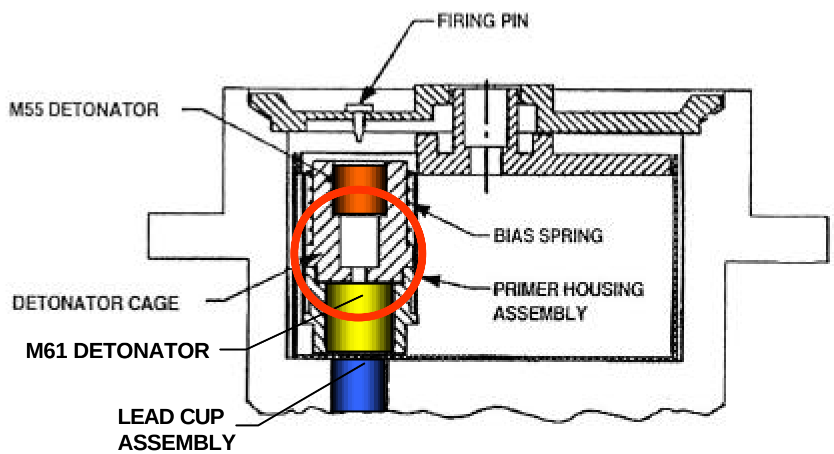
- 99% All Fire Drop Height = 2.89 in, Avg Dent = .013 in
- Output Test #1 0/100 Low Order, Avg Dent = .012 in
- Output Test #2 1/100 Low Order, Avg Dent = .014 in (L.O. = .001 in)

- 99% All Fire Drop Height = 2.91 in, Avg Dent = .020 in
- Output @ -50F 4/100 Low Order, Avg Dent = .018 in (L.O. = .002, .003, .004, .009 in)

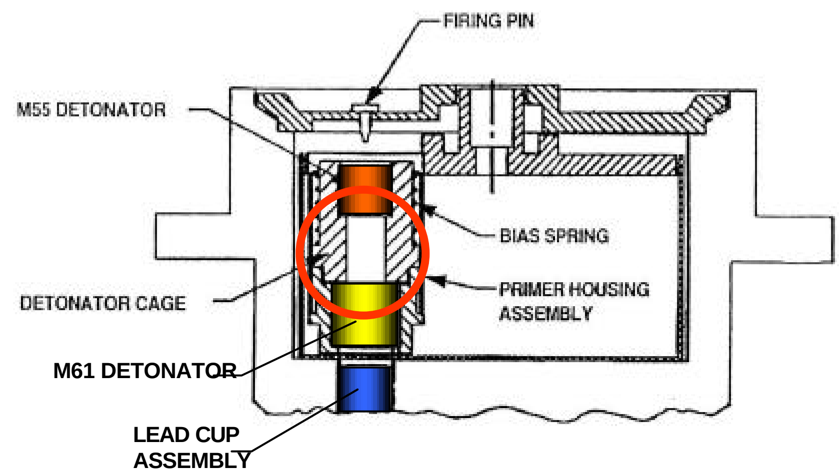
Committed to Excellence

Quick Fix #1
To Get M745 Production Restarted

Control Group



Modified Group



Enlarged blast hole in M55 detonator cage

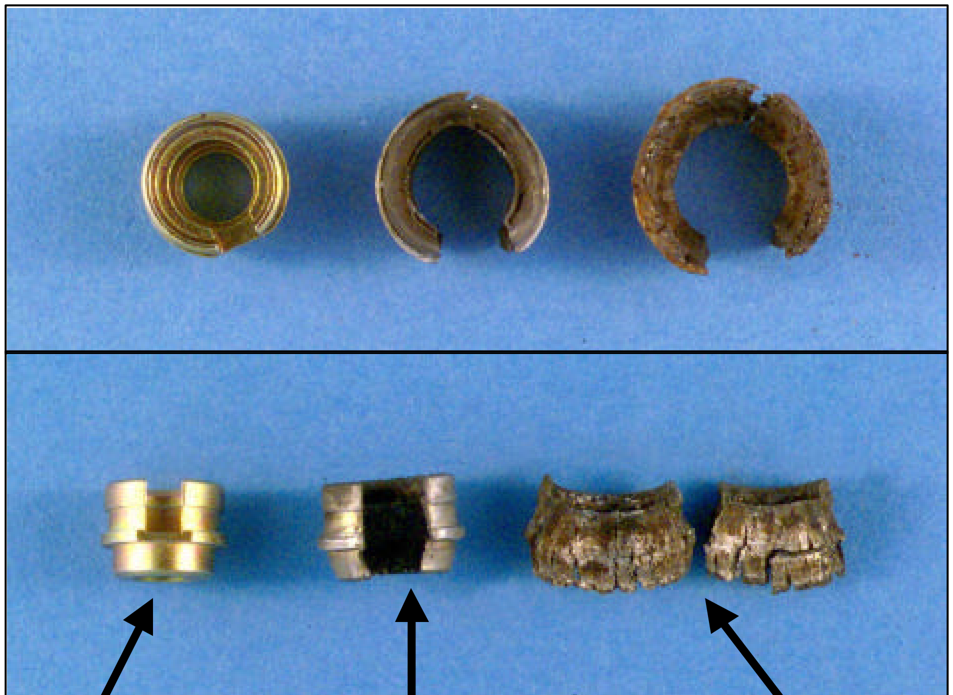
Ballistic Test	Controls	Modified
Hot (+145F)	0/50	0/49
Cold (-50F)	7/41 (17%)	0/49

(as of date)

2/n

Committed to Excellence

M61 Detonator Holder



Virgin Part

Low Order

High Order

M61 Detonator Holder

(Close-up)

High Order

Low Order

Committed to Excellence

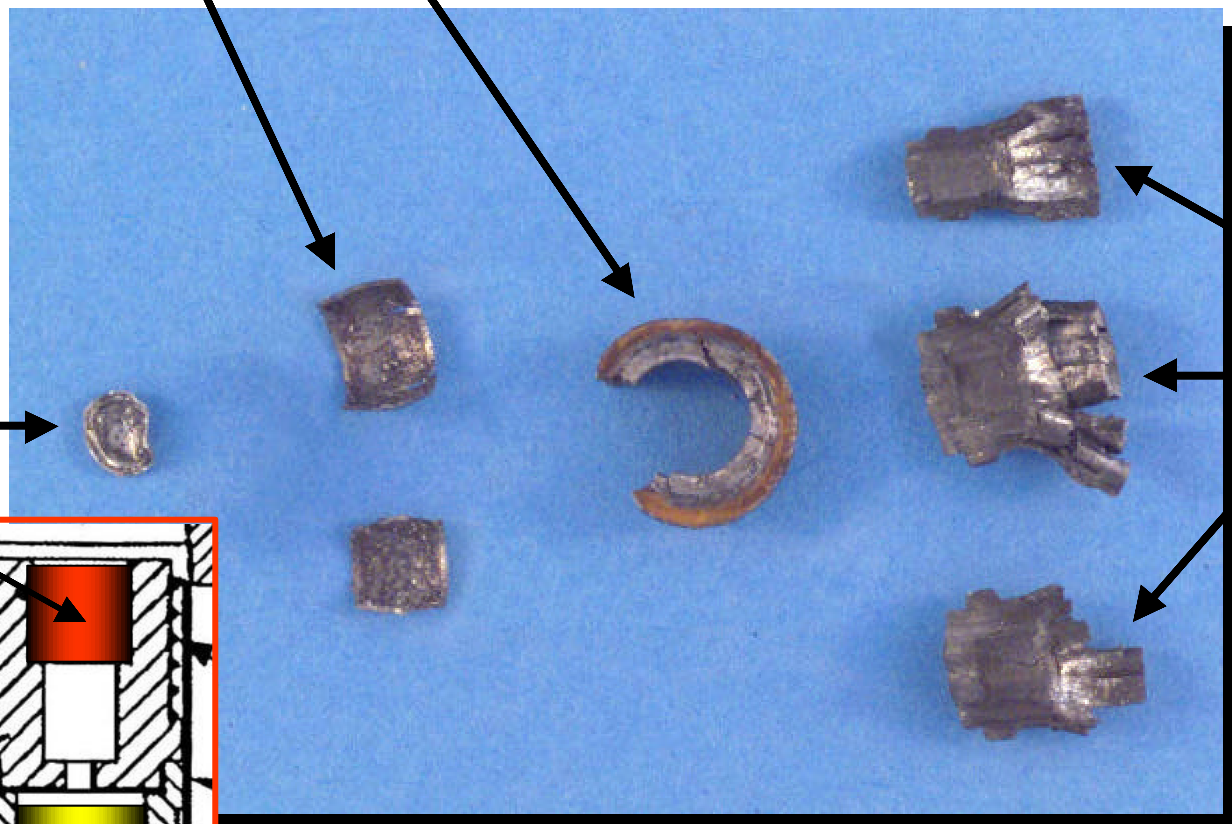
Detonator Housing Assembly

M61 Det Cup

M61 Det Holder

M61 Output Disc

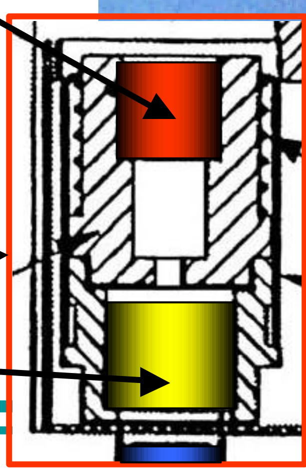
M55 Det Cage



M55

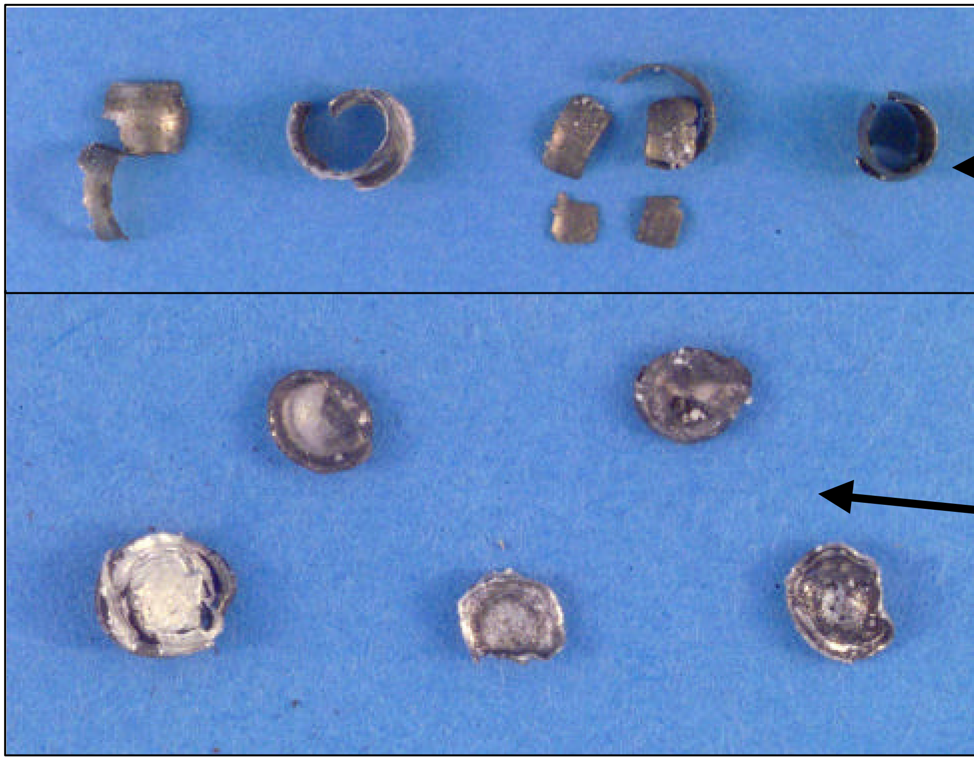
Det Cage

M61



Committed to Excellence

M61 Det Cups and Output Discs



Detonator Cups

Output Discs

Quick Fix #2

Allow Production of New “Good” Detonators for M734A1

- Increase Quantity of Lead Azide
- Decrease Quantity of RDX
- All else remains the same
  (amt of NOL130, steel cup, steel input/output discs, test req’ts)

Old Recipe

M61 Stab Detonator - 153 mg	
NOL 130 Primer Mix	40 mg (min)
Lead Azide, RD1333	80 mg (min)
RDX	33 mg (apx)

New Recipe

M61 Stab Detonator - 169 mg	
NOL 130 Primer Mix	40 mg (min)
Lead Azide, RD1333	104 mg (min)
RDX	25 mg (apx)

M61 Configurations

Modifications

Features

	TDP Req't	Previous Lots	M734A1 MOD 1	MOD 2	MOD 3	MOD 4	MOD 5	MOD 6
NOL 130 Wt (mg)	40 min, (42.5 adv)	41	40	?	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2
Length (in)	-	.021	.022	.024				
Pressure (psi)	45,000	45,000	45,000	60,000				
RD 1333 Wt (mg)	80 min, (85 adv)	81	104	?	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 1
Length (in)	-	.068	.085	.080				
Pressure (psi)	10,000	10,000	10,000	20,000				
RDX Wt (mg)	TBD, (32.5 adv)	33	25	?	Same as Mod 1 or Mod 2	? .045 see note 1 & 2	Same as Mod 1 or Mod 2	? .045 see note 1 & 2
Length (in)	-	.045	.037	.040				
Pressure (psi)	10,000	10,000	10,000	15,000		10 or 15K		10 or 15K
Cup Mat'l	305 Stainless	305 Stainless	305 Stainless	305 Stainless	1100 Aluminum	1100 Aluminum	1100 Aluminum .010 with .002 Thk coined bottom	1100 Aluminum .010 with .002 Thk coined bottom
Thickness (in)	.010 ± .001	.010	.010	.010	.010	.010		
Input Disc Mat'l	302 Stainless	302 Stainless	302 Stainless	302 Stainless	1100 Aluminum	1100 Aluminum	N/A	N/A
Thickness (in)	.00065 ± .00015	0.0006	0.0006	0.0006	0.002	0.002		
Output Disc Mat'l	302 Stainless	302 Stainless	302 Stainless	302 Stainless	302 Stainless	1100 Aluminum	302 Stainless	1100 Aluminum
Thickness (in)	.010 ± .001	.010	.010	.010	.010	0.005	.010	0.005

M61 Configuration

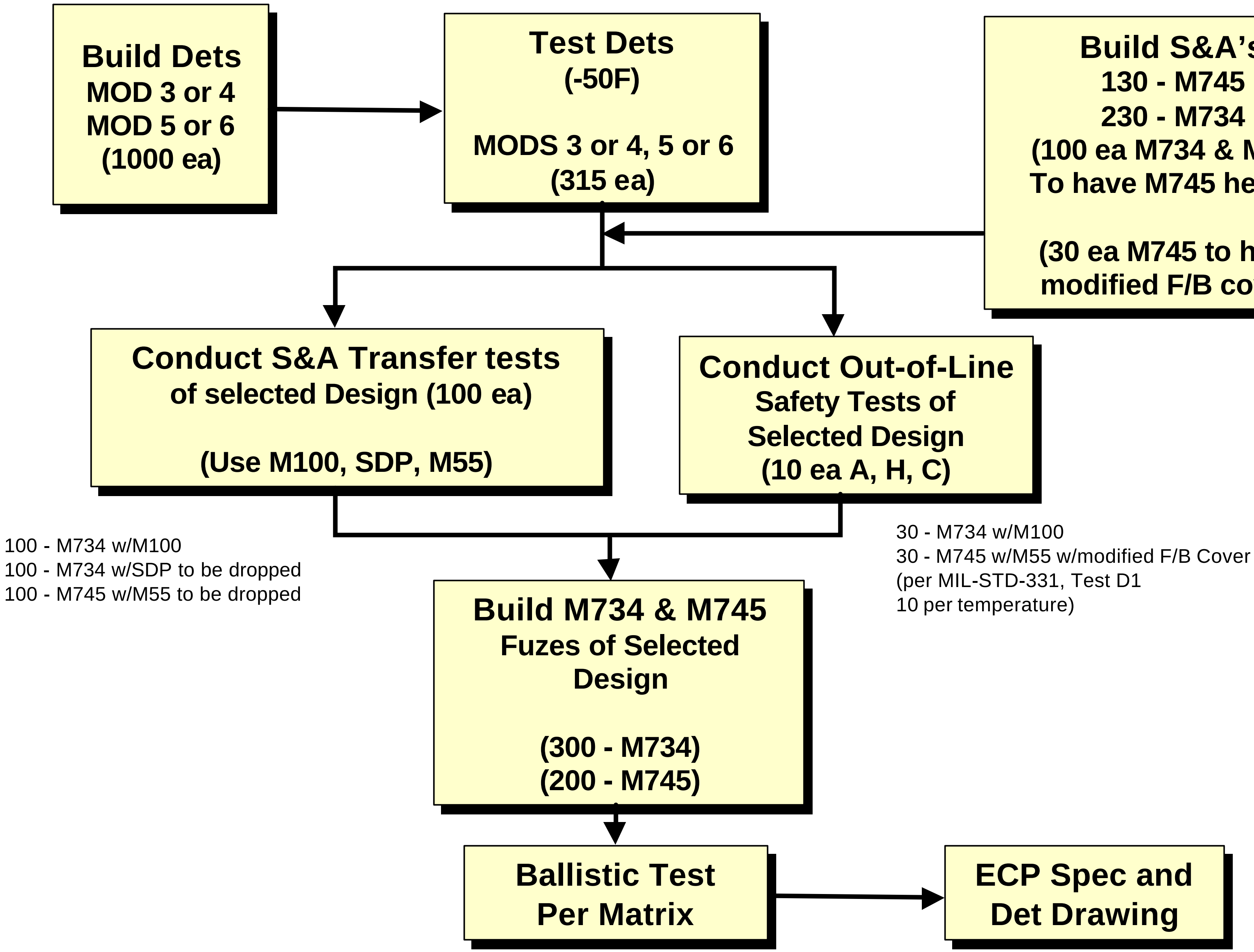
Features

	TDP Req't	Previous Lots	M734A1 MOD 1	MOD 2	MOD 3	MOD 4	MOD 5	MOD 6
NOL 130 Wt (mg) Length (in) Pressure (psi)	40 min, (42.5 adv) - 45,000	41 .03 45,000	40 .022 45,000	? .024 60,000	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2
RD 1333 Wt (mg) Length (in) Pressure (psi)	80 min, (85 adv) - 10,000				Same as Mod 1 or Mod 2	Same as Mod 1 or Mod 2		
RDX Wt (mg) Length (in) Pressure (psi)	TBD, (32.5 adv) - 10,000				Same as Mod 1 or Mod 2	? .045 see note 1 & 2 10 or 15K		
Cup Mat'l Thickness (in)	305 Stainless .010 ± .001				1100 Aluminum .010	1100 Aluminum .010		
Input Disc Mat'l Thickness (in)	302 Stainless .00065 ± .00015				1100 Aluminum 0.002	1100 Aluminum 0.002		
Output Disc Mat'l Thickness (in)	302 Stainless .010 ± .001				.010	0.005		

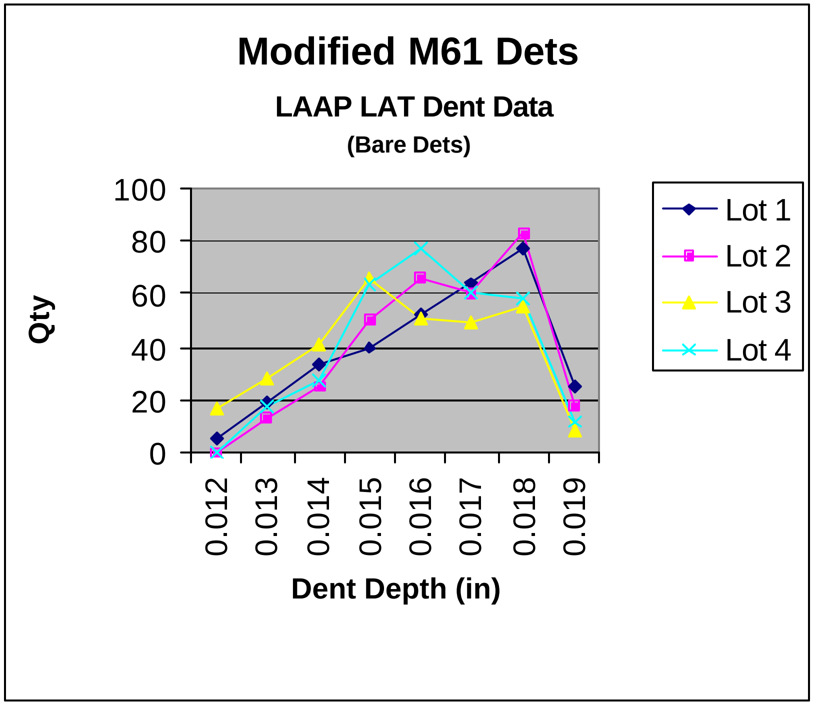
Notes:
1) Since these mods use a .005" thk output dis… more in length of the RDX …
2) Since these mods use a .002" thk input disc … disc … use…
No allowance has been made for this.

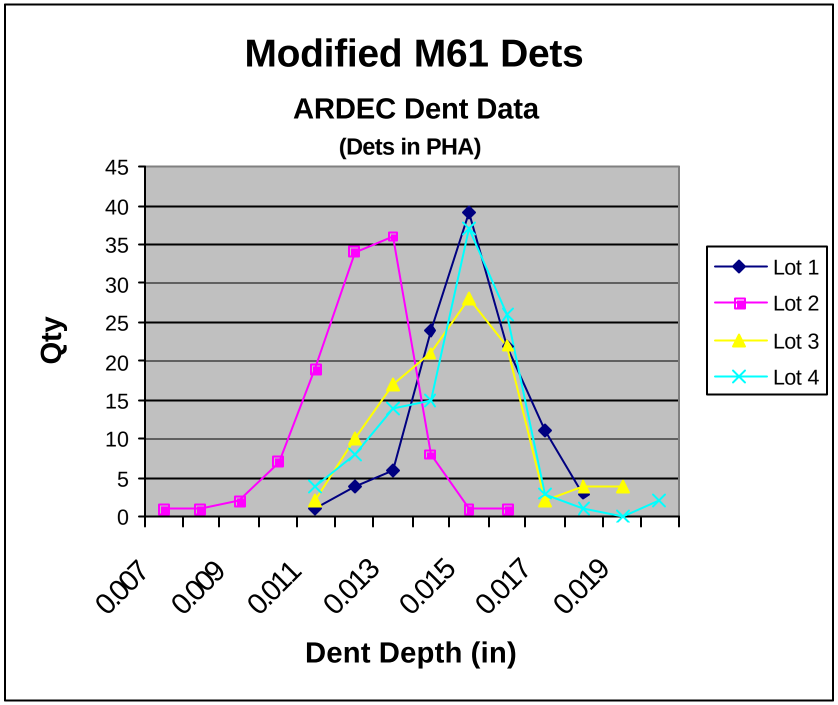
M734A1 MOD 1	MOD 6
40 mg NOL 130 .022 in 45,000 psi	40 mg NOL 130 .022 in 45,000 psi
104 mg Lead Azide .085 in 10,000 psi	104 mg Lead Azide .085 in 10,000 psi
25 mg RDX .037 in 10,000 psi	25 mg RDX .037 in 10,000 psi
305 Stainless Cup .010 in	1100 Al Coined Cup .010 in
302 SS Input Disc 0.0006 in	N/A
302 SS Output Disc .010 in	1100 Al Output Disc .005 in

Block Diagram of Testing



LAAP and ARDEC Lab Test Data





Committed to Excellence

Ballistic Test Matrix

BALLISTIC TEST MATRIX

FUZE	SETTING	TEMP	CHG	QTY
M734	PRX	-50F	0	50
M734	PRX	+145F	4	50
M734	DLY	-50F	0	150
M734	DLY	+145F	4	50
				300

FUZE	SETTING	TEMP	CHG	QTY
M745	N/A	-50F	0	150
M745	N/A	+145F	4	50
				200

Notes:
1) Shoot chg 0 on inert 60mm projo's for recovery.
2) Shoot chg 4 on HE I-81 projo's.

Advantages of New Detonator Design

- Eliminate separate input disc
- Eliminate "discing" operation
- Eliminate inspection for disc (100% by hand)
- New aluminum cup more cost effective than steel cup
- Easier to obtain final overall length and tighter crimp using aluminum versus steel
- New test set-up uses standard hardware, readily available and will better discriminate between good dets and bad dets (due to lower input energy req't, output dent test req't, and temperature testing)

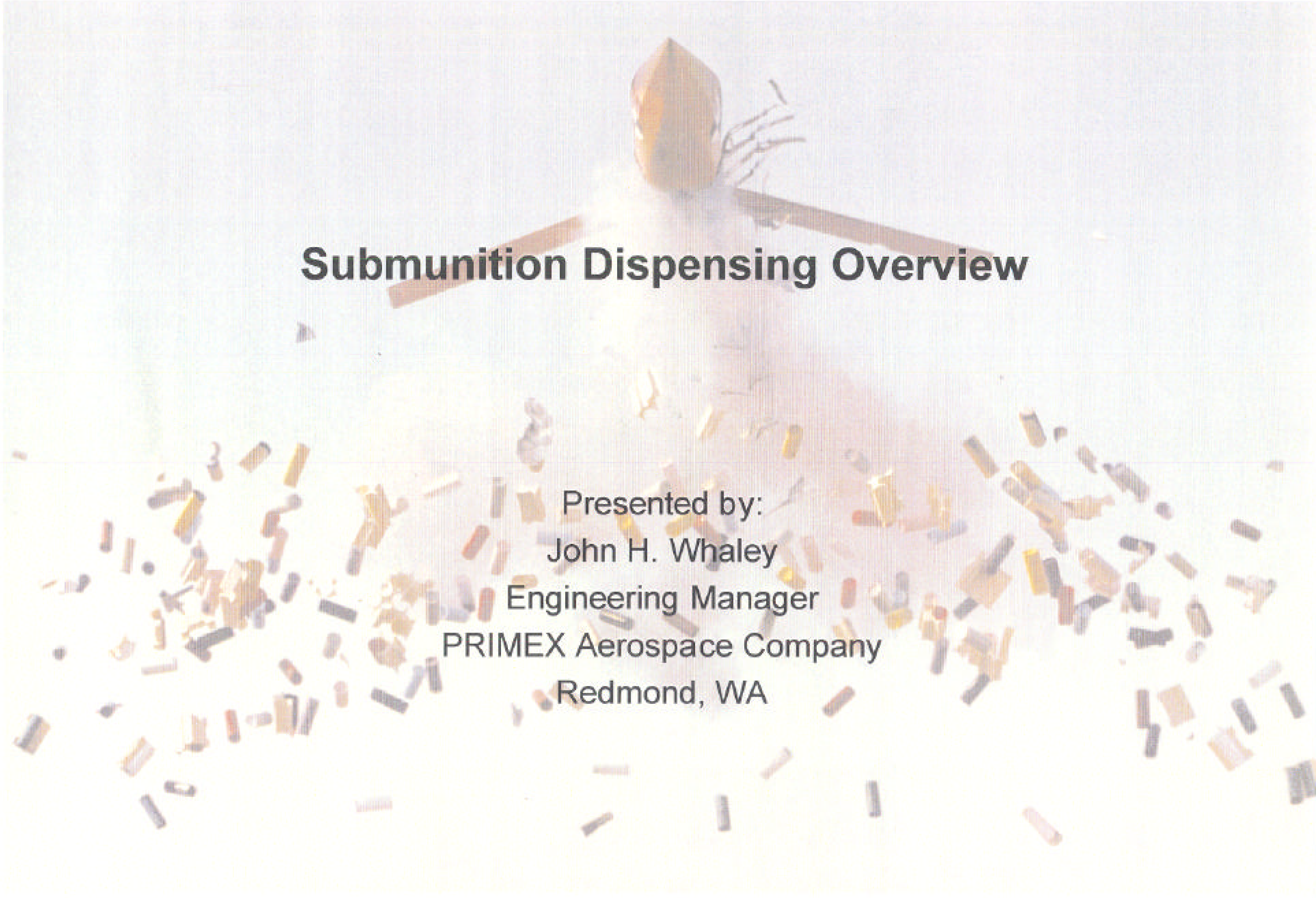
Summary

- M745 fuze experienced an excessive number of duds during cartridge testing
- Failure analysis initiated
- Discovered that the M61 detonator was functioning low order
- Quick fix #1 - to get M745 production restarted
- Learned that the M61 det had too little lead azide to support a DDT (which caused it to function low order)
- Quick fix #2 - for M734A1 production
- Final design solution resulted in a revamped detonator

Conclusion

- Detonators **CAN** function low order (contrary to what experts say)
- Temperature testing during LAT (esp @ cold) can assist in discriminating between good and bad lots
- Now being implemented on the M734A1 and XM783 mortar fuzes
- Increased reliability functioning of M734A1, M734, XM783 and M745 fuzes through improved performance of the M61
- Reduced costs to the Government by eliminating the need to rework fuzes, conduct additional tests or accept inferior product

AEROSPACE COMPANY



Submunition Dispensing Overview

Presented by:

John H. Whaley

Engineering Manager

PRIMEX Aerospace Company

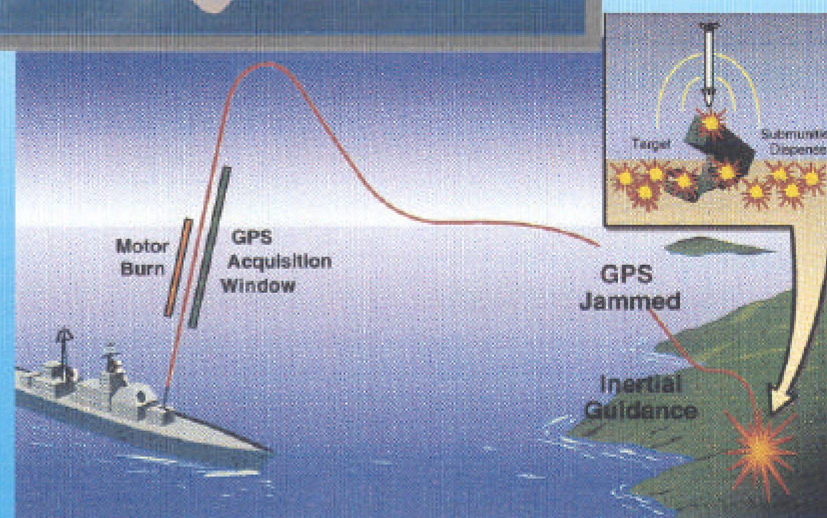
Redmond, WA

Background

- Historical Perspectives
- Developments In Platforms
- Projectiles
- Missiles
- Cost Drivers
- Cost-per-Kill
- System Complexity

The Need For Dispensing

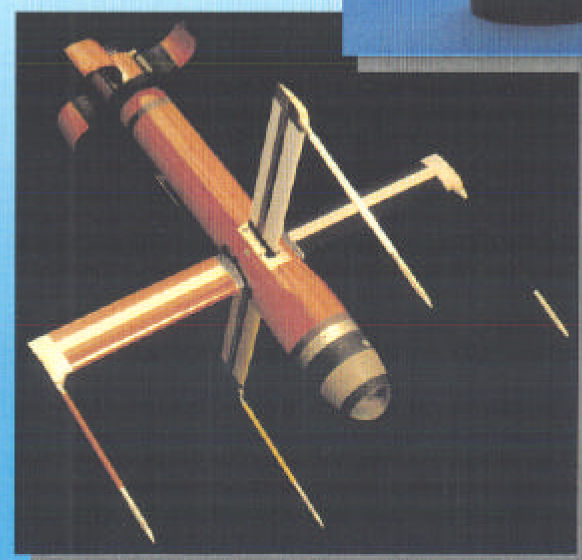
- Tactical Advantages
- Stand-off Weapons
- Staged Events
  - Dual Stage Events
  - Timed Events
- Accuracy Improvements
  - Guidance
  - GPS Technology
- Coverage/Effectiveness Improvements
  - Improved Munitions
  - Improved Coverage



PRIMEX
AEROSPACE COMPANY

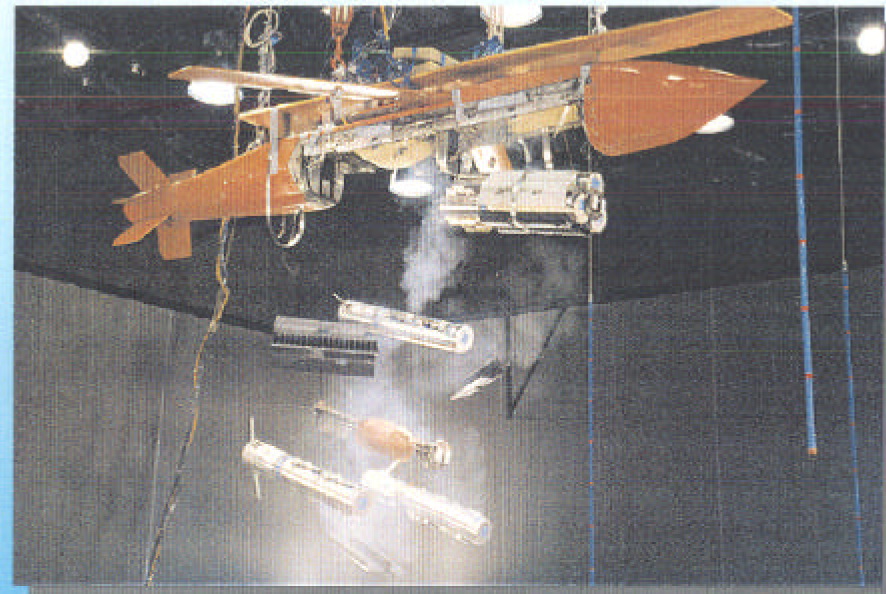
Munition Variations

- Grenades & Standard Munitions
  - XM80 & XM85 Grenades
- Mines & "Placed" Munitions
- Smart Munitions
  - BAT
  - BLU-108 Anti-Armor



Fuze & Timing Variations

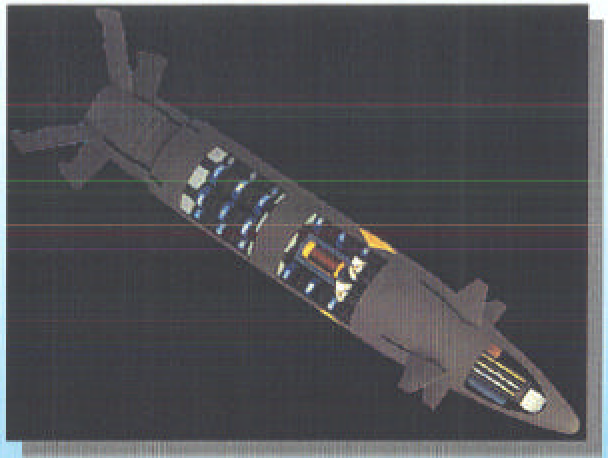
- Mechanical Fuzes/Timers
  - Nose Mount, Manual Set, Lanyards, etc.
- Pyrotechnic Fuzes/Timers
  - Nominally Pyrotechnic Delay Mixtures
- Electrical Fuzes/Timers
  - Conventional RC Timing Circuits
  - Lanyard or Timer Intiated
- Electronic/Software Fuzes/Timers
  - Incorporated Function Within "Mission Computer"

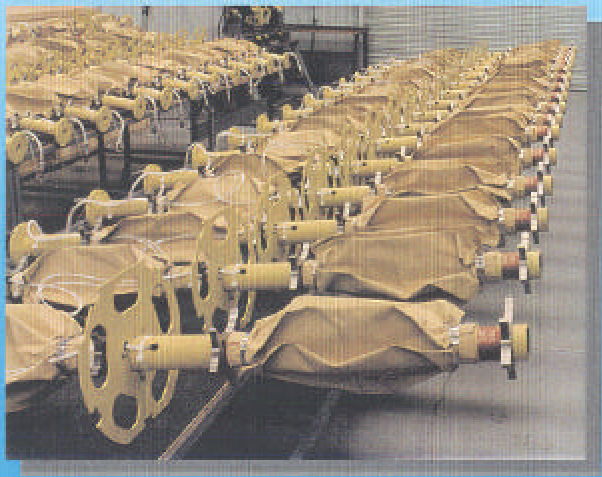


PRIMEX AEROSPACE COMPANY

Design Constraints

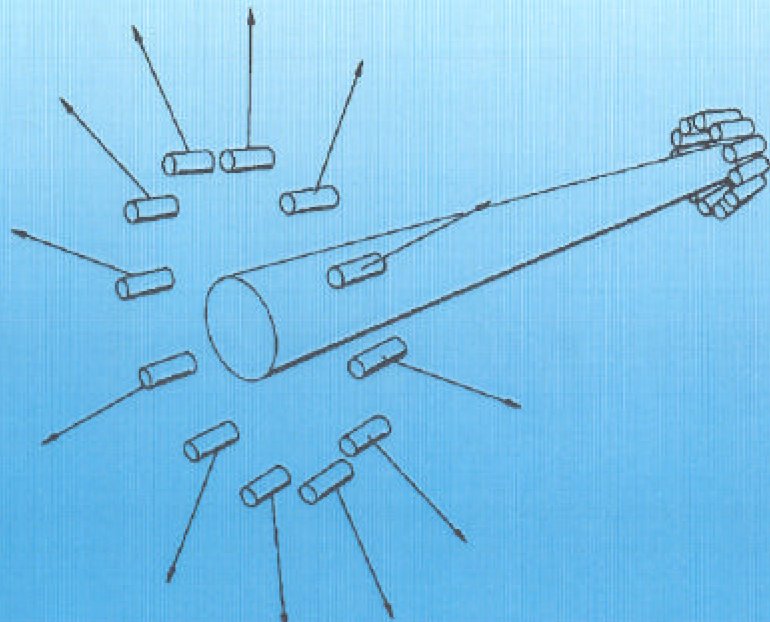
- Volume
- Weight & C.G. Requirements
- Environmental Exposure & Storage
- Structure & Loading Constraints
  - Shipping, Launch, etc.
- Safety
  - Safe Operation
  - Insensitive Munitions
- Performance
  - Ground Patterns, Effectiveness
- Cost

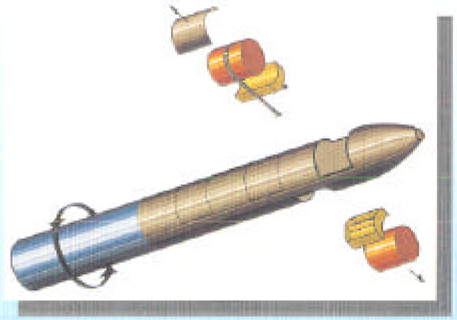


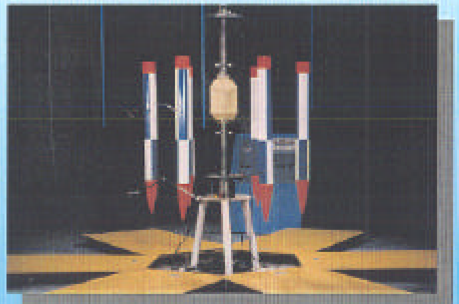


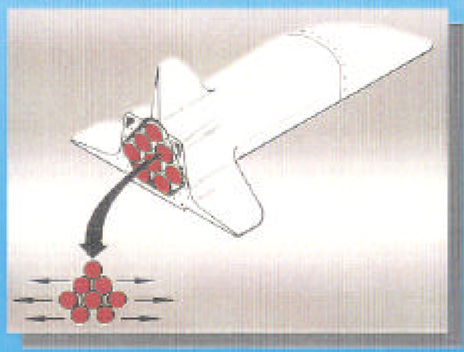
Dispenser Variations

- Spin Dispensers
- Center Core Burster
- Piston Concepts
- Fabric Bladder Concepts
- Metal Bladder Concepts









PRIMEX AEROSPACE COMPANY

Additional Applications

- Deployment Mechanisms
- Inflatable Structures
- Impact Attenuation

Development of a Unique Hypervelocity Sabot

Presented At:

Munitions Technology Symposium VII

April 10-12, 2000

Pleasanton, CA

Presented By: Moreno White

This work was funded by BMDO and administered by ARDEC under a prime contract with GE (currently Lockheed Martin, Orlando). Program Management responsibility was under SSDC.

SPARTA, Inc.
Composite Products Operation
10540 Heater Court
San Diego, California 92121-4111
(858) 455 -1650 Fax (858) 455 -1698
Contact CPO at *composites@sparta.com*
Visit our Website at *www.composites.sparta.com*

D2 Projectile Requirements

	Strategic	TMD
Mission Launcher	HTK Fixed Site EMG	HTK Mobile ETC
Launch Mass/Dia	7.5 kg/105 mm	7-8 kg/105 mm
Launch Velocity	4 km/sec	2.5 km/sec
Launch Acceleration	100,000 gees axial;5 kgee lateral	70,000 gees axial/~3 kgee lateral
Max Range	50 km	25 km
Operation	Command Guided w/Terminal Homing	Command Guided
Structure	Boron/Al	Graphite Epoxy
Aeroshell	3° Half Angle Cone with 6° Aft Flare	3° Half Angle Cone with 6° Aft Flare
Launch Package	Saboted Round, cc Nosetip, Carbon-Phenolic Aero Heat Shield, Tungsten Carbide Penetrator	Saboted Round, Aluminum Nosecone*, No Heat Shield, Tungsten Carbide Penetrator

*Test Bed Configuration

D2 Test Bed Projectile

Initial D2 Sabot Concept

Design Drivers

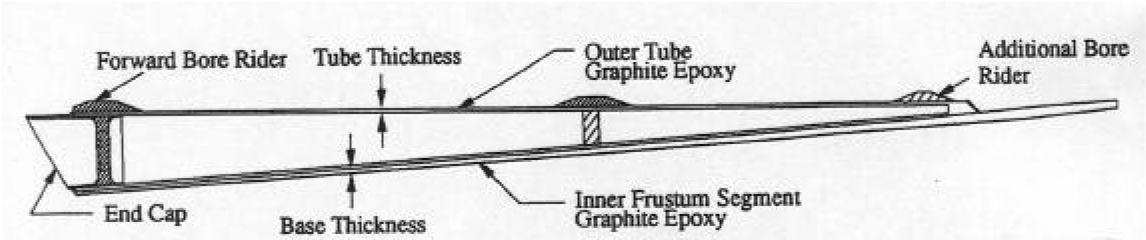
High Launch Accelerations
  - Axial (100 Kgee Strategic, 70 kgee TMD)
  - Balloting (5 Kgee Strategic and TMD)
- In-Bore Thermal & Electrical Environment
- High In-Bore Pressure (>7100 psi)
  - Compressed Gas, Forward of Projectile
- Large Uncertainty in Load
  - Balloting
  - In-Bore Pressure (Air Column Compression, Shockwave Interaction)

Materials

- High Specific Strength
  - Graphite/Epoxy
  - Continuous Fiber
- Non-Conducting Bore Riders
  - Glass Epoxy

Design

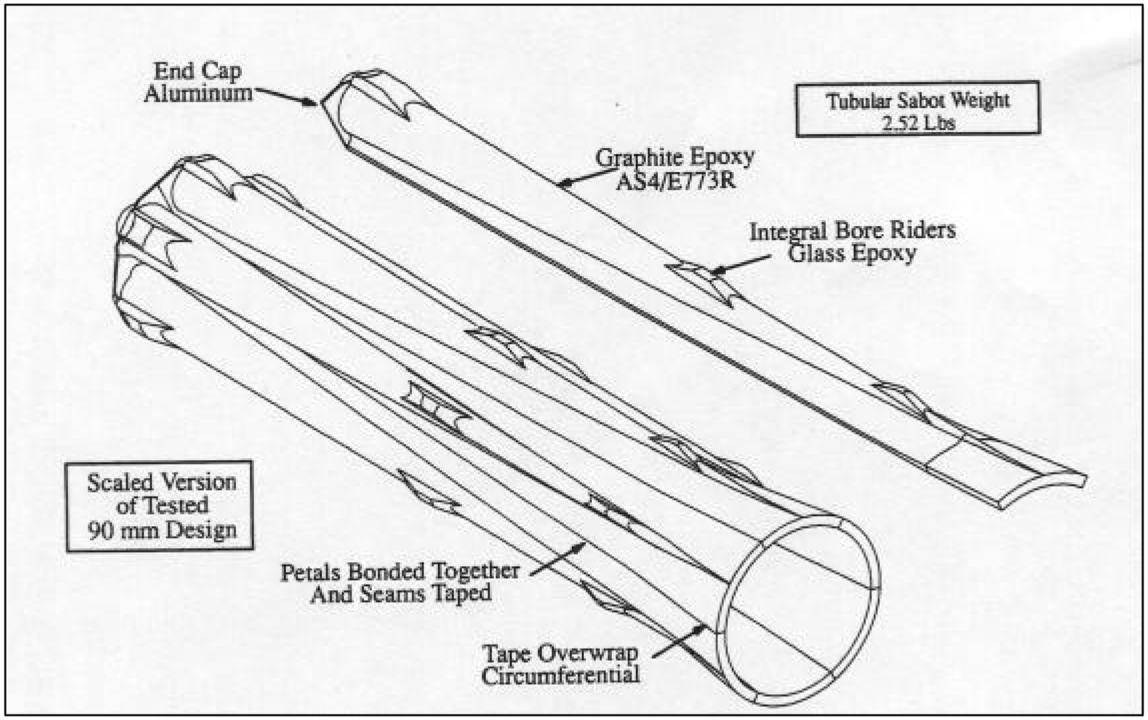
- Minimum Mass
  - Conformal/Conical
  - Internal Bulkheads
- Minimize Separation Forces
  - Multi-Petal Design (6 Petals)



SPARTA Pride In Performance

we offer composite solutions...

D2 Conical Sabot Configuration



SPARTA
Pride In Performance

we offer composite solutions...

Conical Sabot Fabrication

MATERIAL

- **Carbon/Epoxy**
  - AS4/E773R
  - 250°F Cure
- **Glass/Epoxy (Bore Riders)**

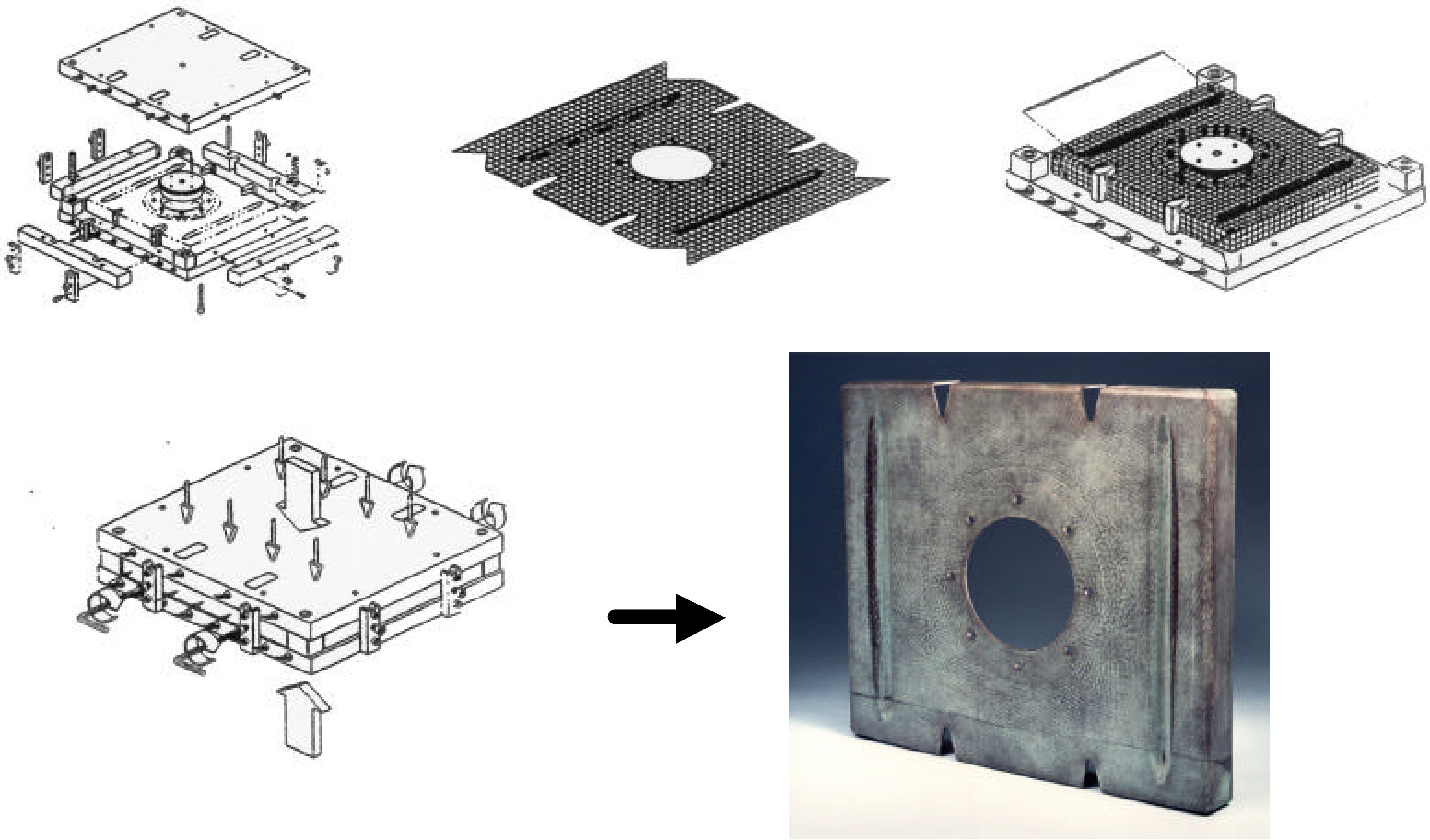
FIBER ARCHITECTURE

- **82% Axial (0°)**
- **18% ± 15° and ±75 ° (4 plys, cone only)**
- **Transition From:**
  - 46 Layers at Aft End to 15 Layers Forward End

FABRICATION STEPS

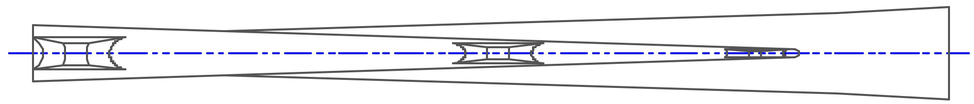
- **Receive Material**
  - Uni-Tape 60% Fv
- **Cut Into Kits Using Steel Rule Dies**
  - Cut Gore Patterns with Drop-Offs: Cone, Frustrum
- **Lay-Up Gore Sections on Separate Male Tooling for Cone & Frustum**
  - Minimized Weak Points by Circumferentially Staggering Gore Plys
  - Controlled Thickness Variation Utilizing Ply Drop-Offs
  - Preliminary De-Bulk on Independent Tool
- **Final Sabot Configuration**
  - Cone & Frustum Tool/Components are Placed in Separate Consolidation Tool
  - Glass/Epoxy Bore Riders Laid in Consolidation Tool
  - Uni-tape Added at Cone/Frustum Interface
  - Fully Consolidated As One Piece
  - 250°F
  - Deflash, Machine Forward end and trim to length
- **Bond Bulkheads into Conical Sabot and Install Aluminum End Caps**

Net Shape Compression Molding Sequence

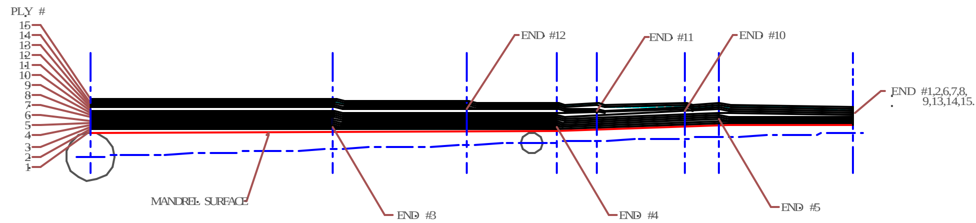


we offer composite solutions...

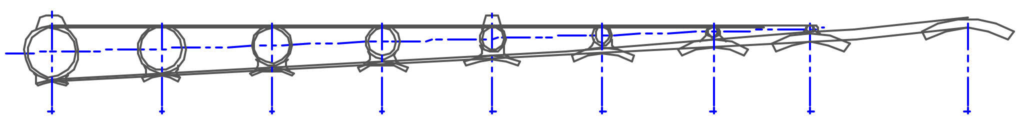
Conical Sabot Lay Up Architecture



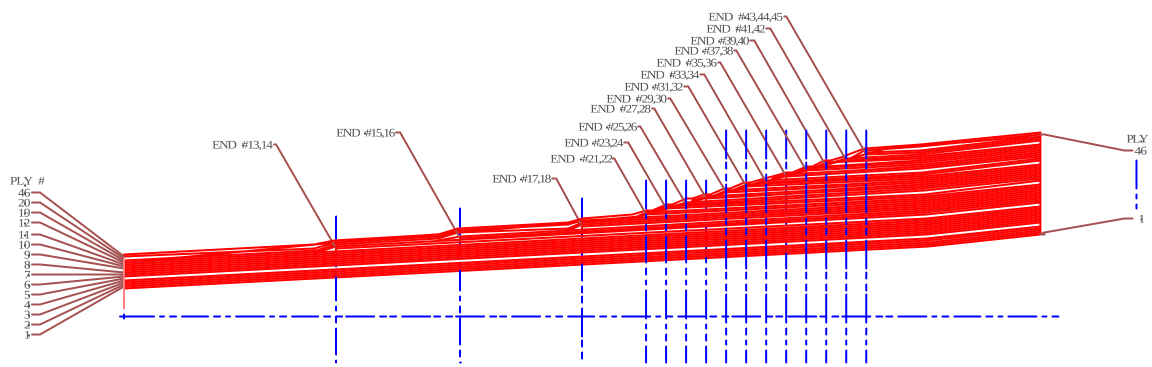
Top View



OUTER CONE PLY LAYUP



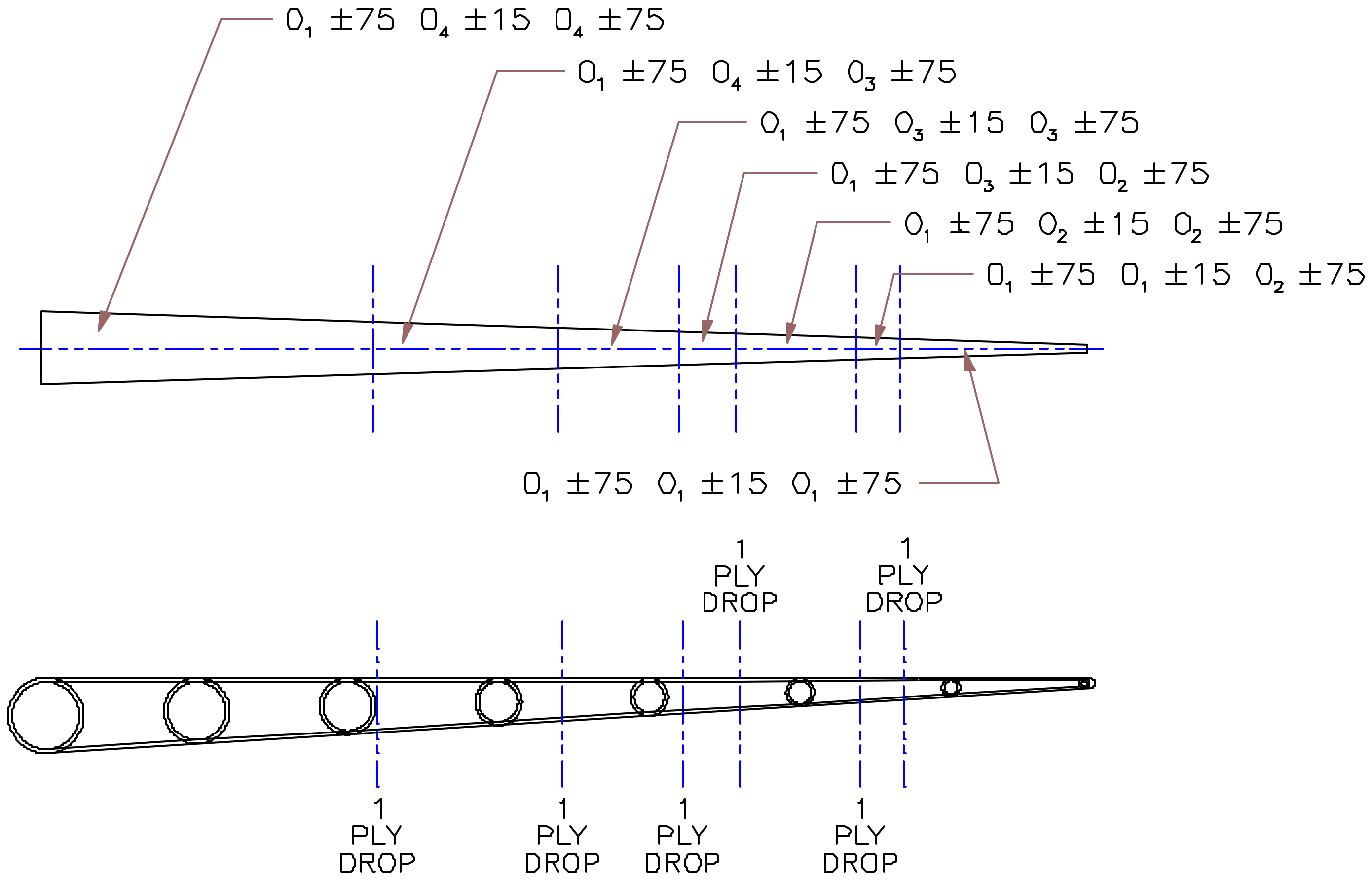
Side View



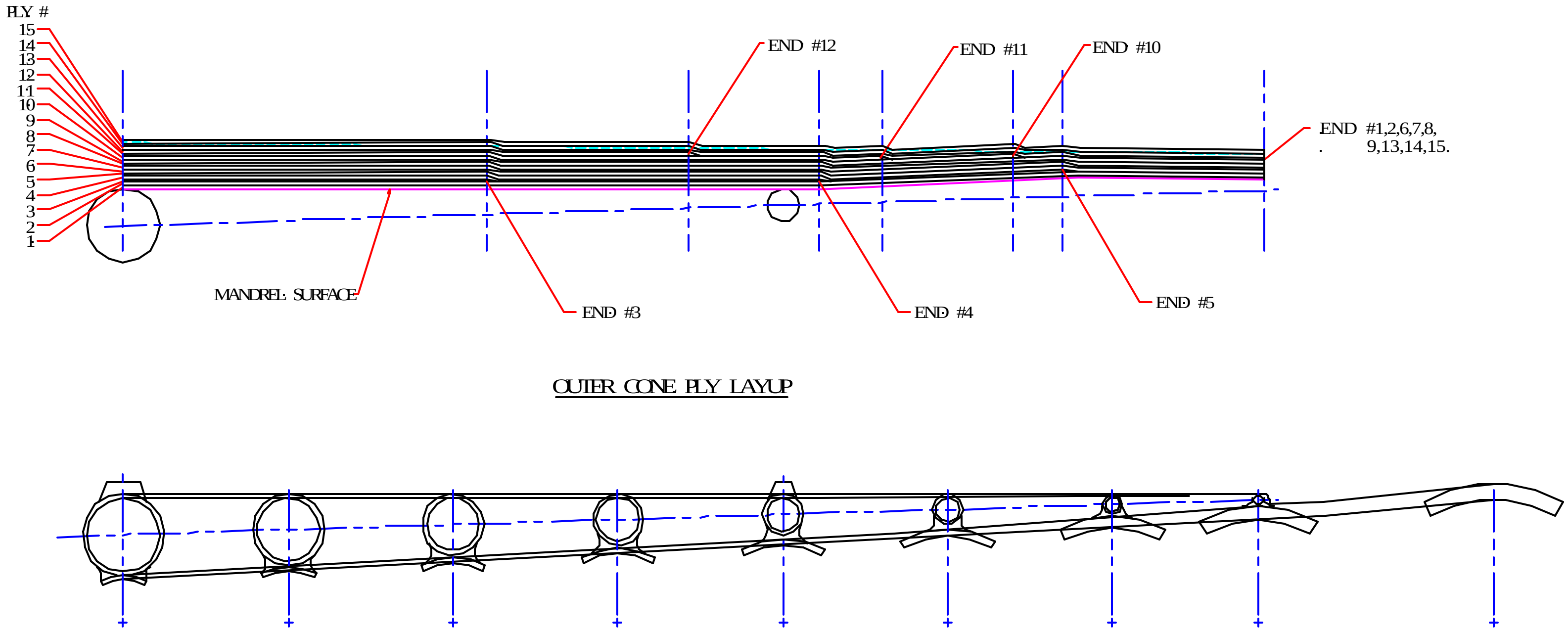
INNER CONE PLY LAYUP

we offer composite solutions...

Cone Ply Orientation and Gore Geometry

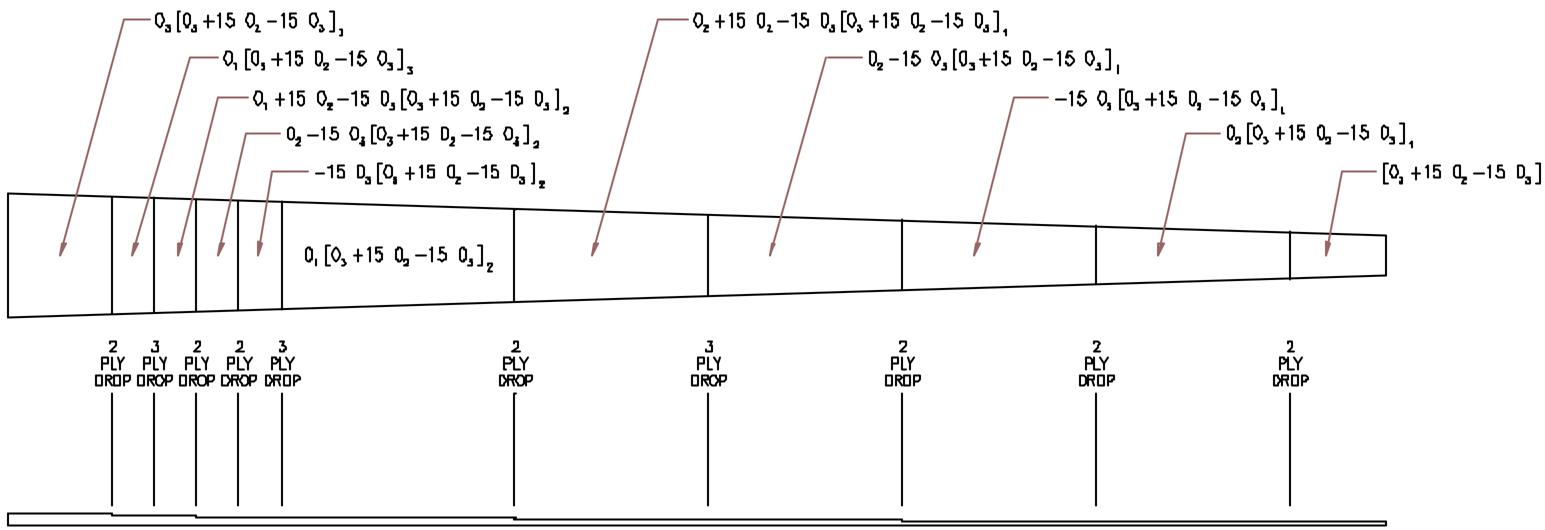


Conical Sabot Cone Lay Up

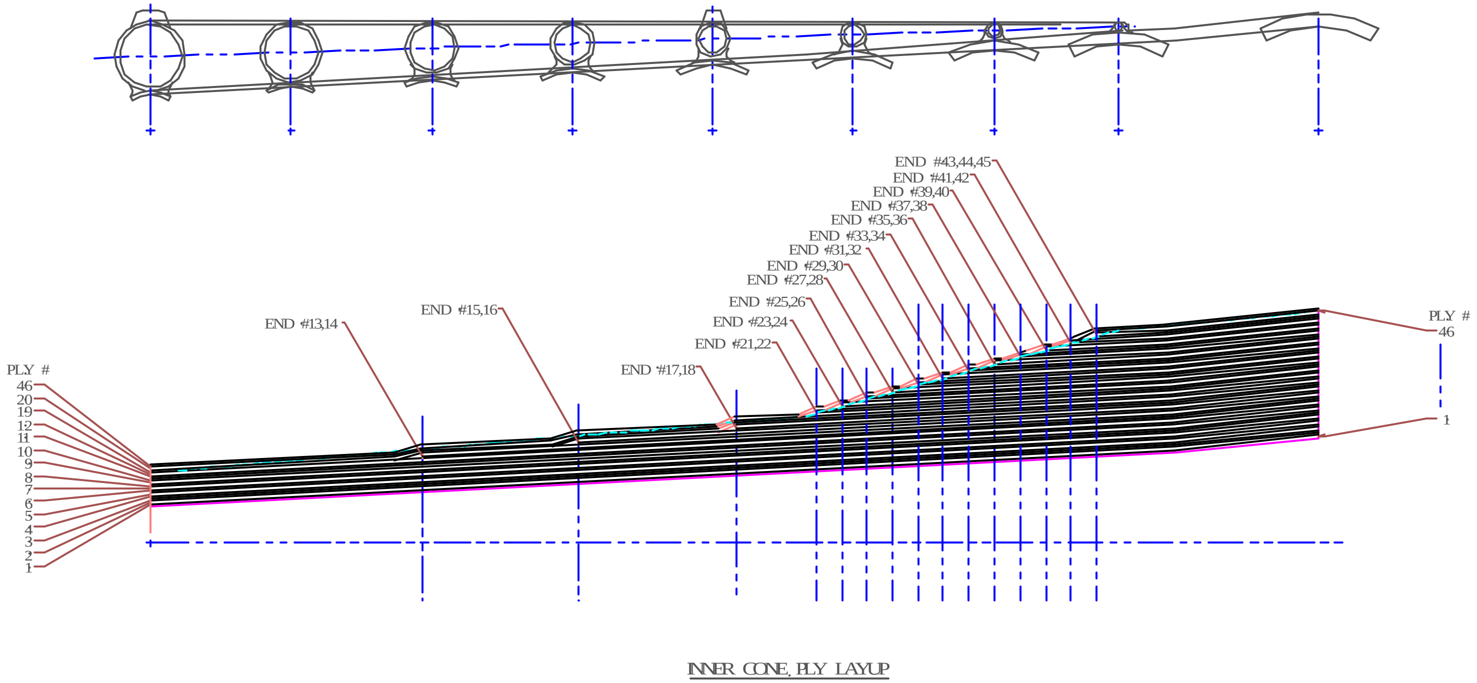


we offer composite solutions...

Frustum Ply Orientation and Gore Geometry



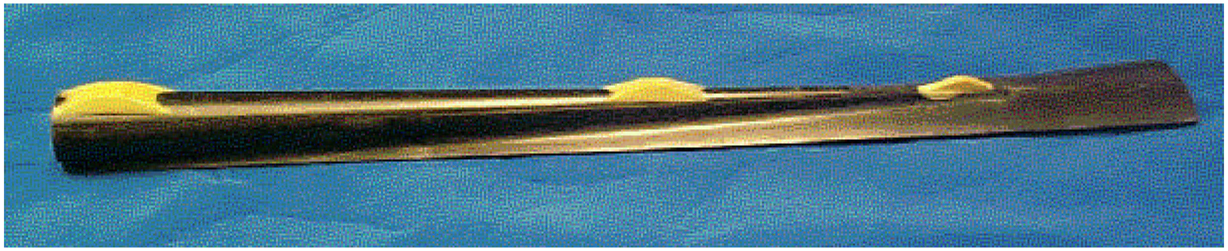
Conical Sabot Frustum Lay Up



SPARTA
Pride In Performance

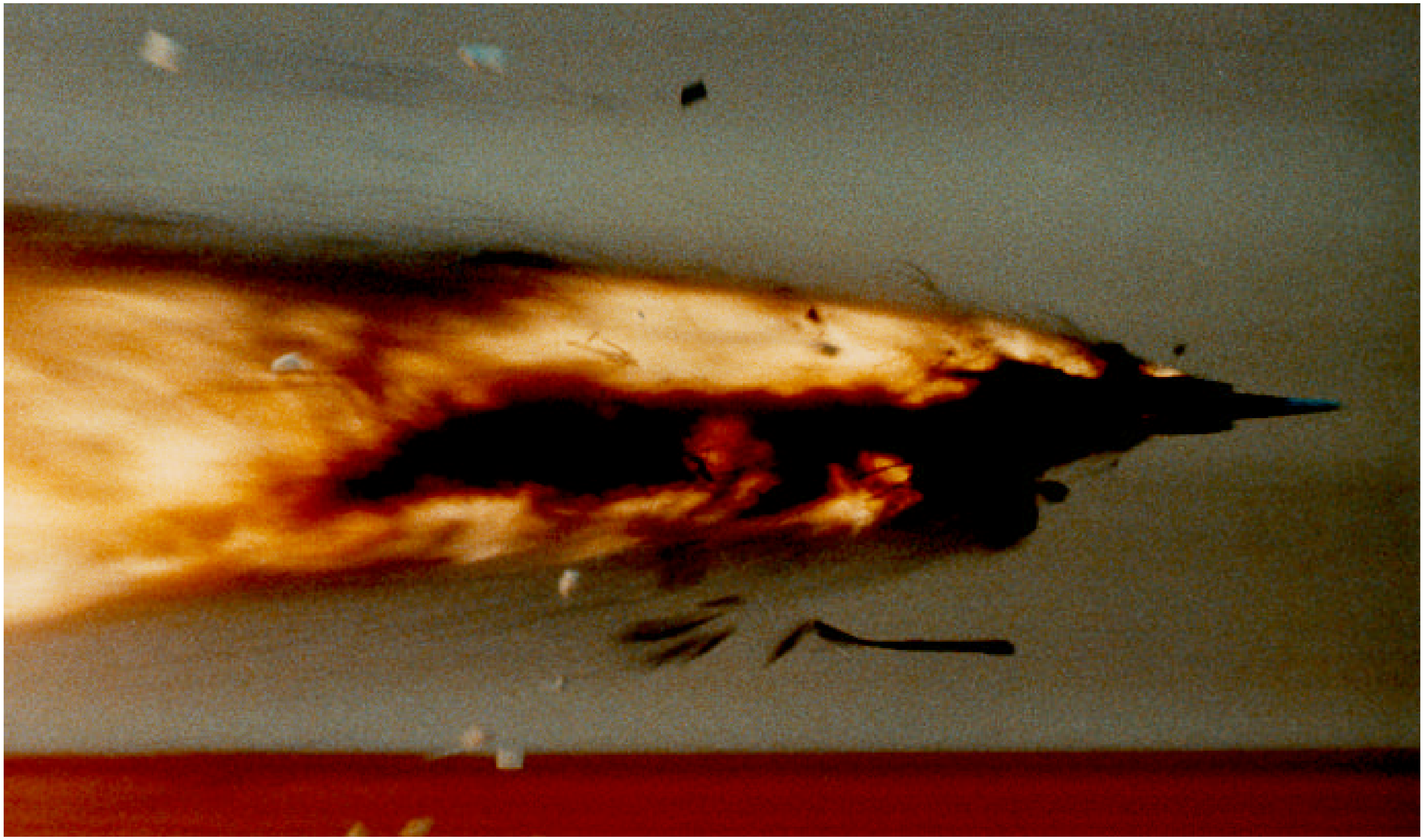
we offer composite solutions…

As Fabricated Conical Sabot



SPARTA
Pride In Performance

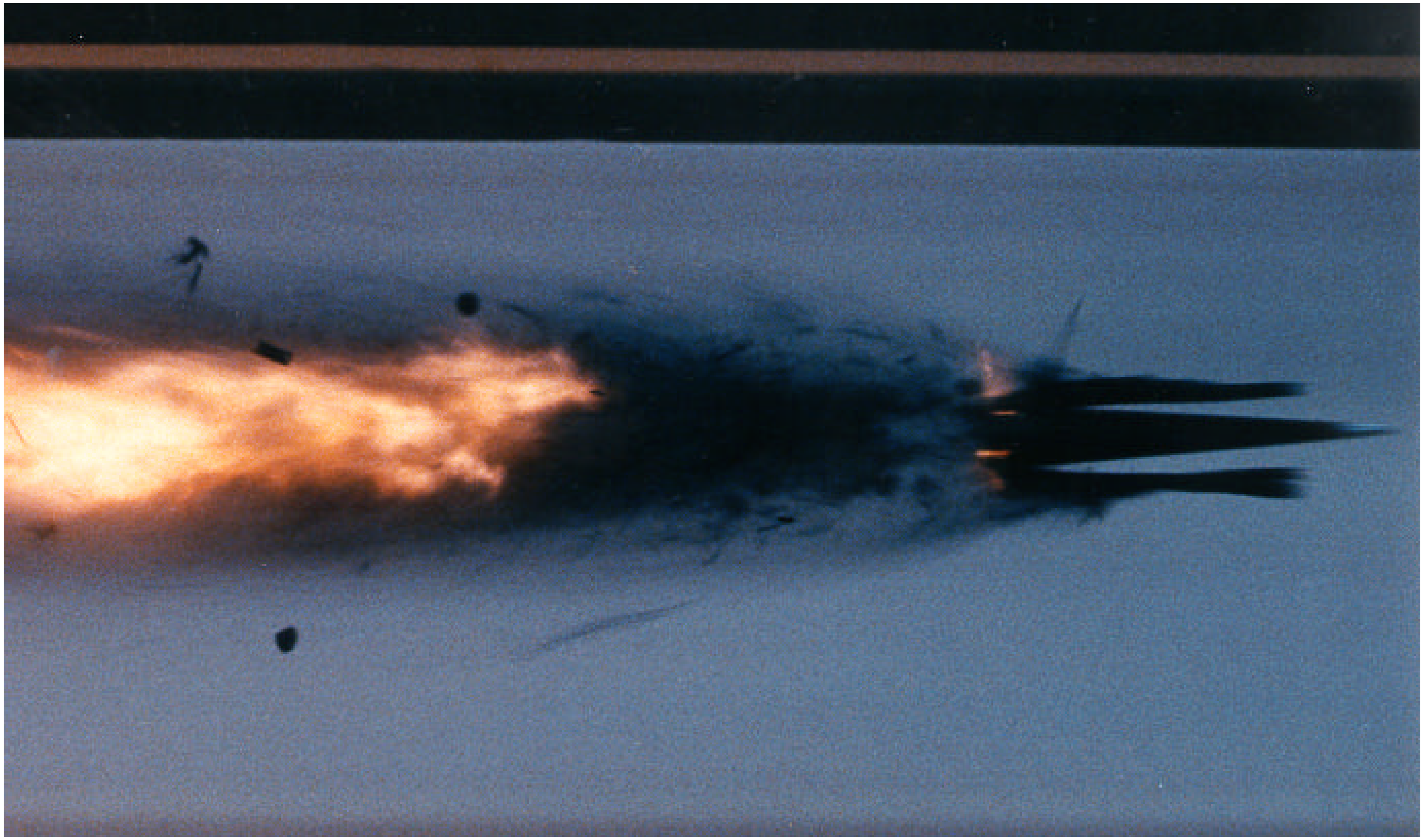
Conical Sabot Separation
5m Down Range/(2.0 km/sec, 60,000 Gee Launch)



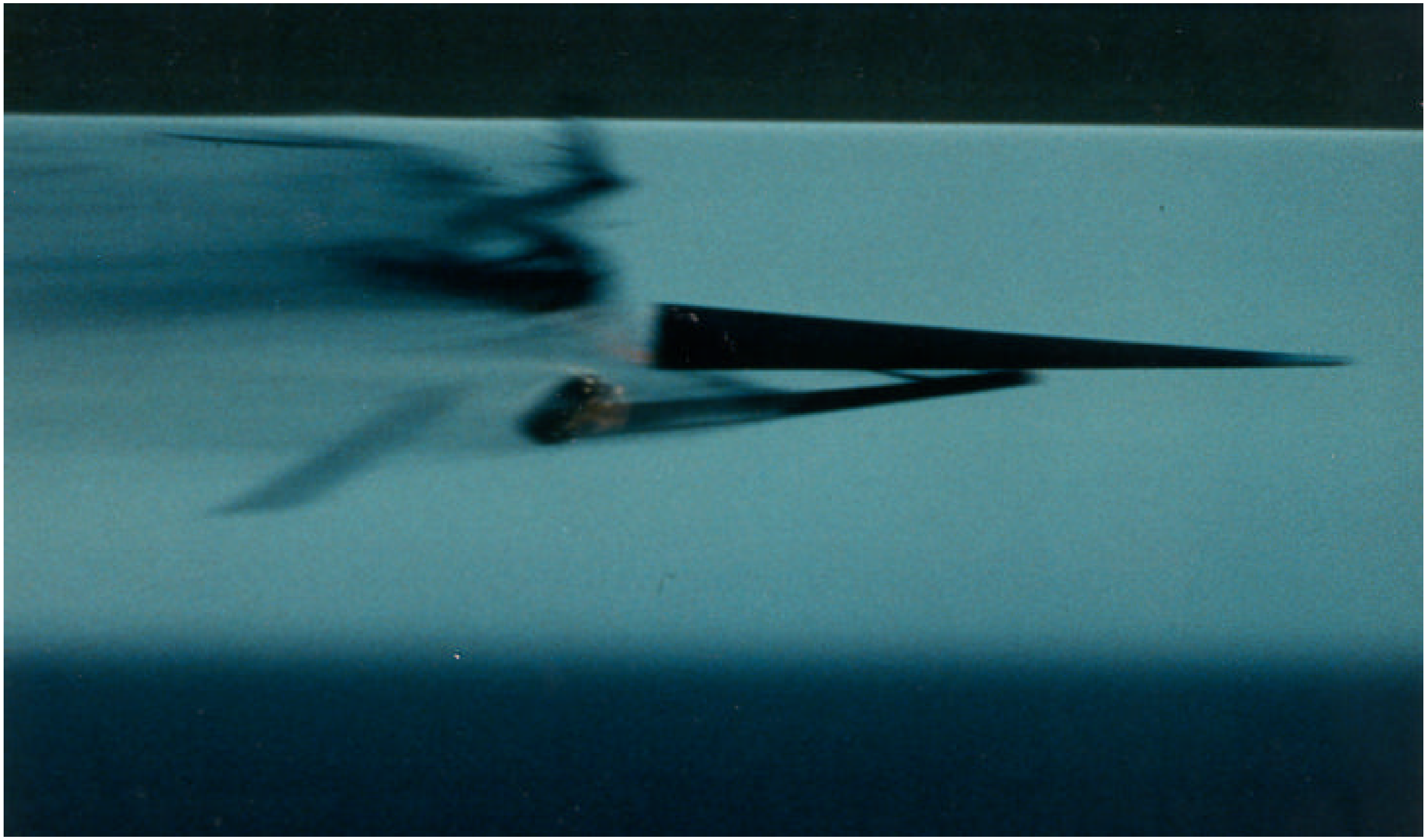
SPARTA
Pride In Performance

we offer composite solutions...

Conical Sabot Separation
10m Down Range/(2.0 km/sec, 60,000 Gee Launch



Conical Sabot Separation
20m Down Range Showing Projectile Tip Off
(2.0 km/sec, 60,000 Gee Launch)



SPARTA
Pride In Performance

Conical Sabot Summary

- **Sabot Mass - 2.52 lbs**
  - **Approximately 42% of Launch Mass**
- **17 Total Shots**
  - **Exit Velocities From 1.46 to 2.1 km/sec**
  - **Failure of All But 2 Shots Above 1.6 km/sec**
  - **Highest Successful Launch Performance : 66 Kgees, 2.05 Km/sec**
- **In-Bore Failures**
  - **Overpressure Due to Compressed Air Column (down-bore films)**
  - **Attributed to Acceleration Excursions from Powder Ignition**

    Verified By Shooting Instrumented Slugs
  - **Sabot Parts Were Sectioned and Analyzed; No Process-Induced Degradation was Found**
- **Sabot Redesign**
  - **Channel Design**
  - **Less Susceptible to In-Bore Overpressure**
  - **Maintain Axial & Lateral Load Capability**

D2 Channel Sabot Design

Primary Driver

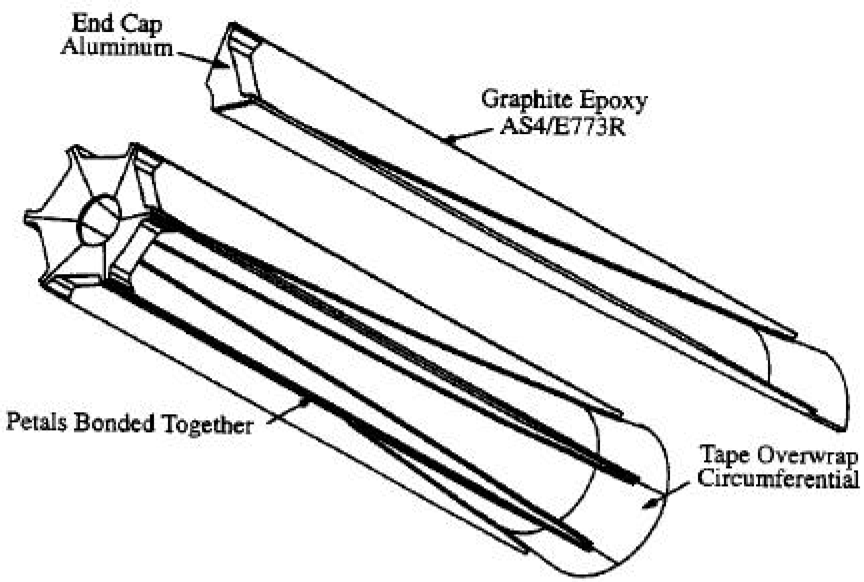
- **Channel Design Eliminates Susceptibility to In-Bore Pressure Excursions**
- **Same Axial and Balloting Loads as Conical Design**
- **Minimize Mass**

Material

- **Continuous Fiber Graphite/Epoxy**
- **Aluminum End Caps**

Design

- **Six-Petal Sabot Configuration**
- **Minimum Mass**
  - Channel Design Was ≈ 3% Heavier Than the Baseline Conical Sabot
- **Simplified Fabrication Process**



Channel Sabot Fabrication

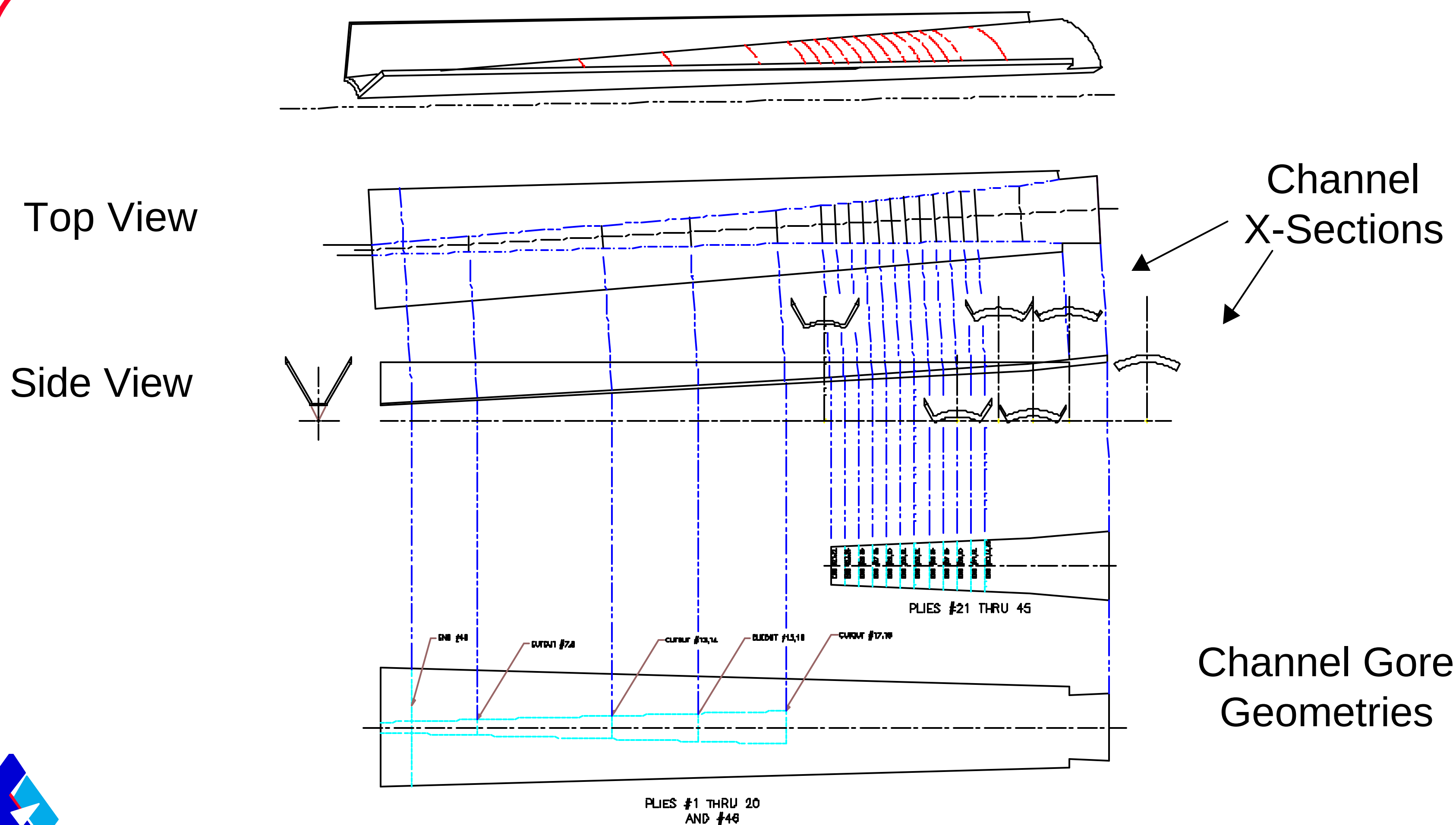
MATERIAL

- **Carbon/Epoxy**
  - AS4/E773R
  - 250°F Cure

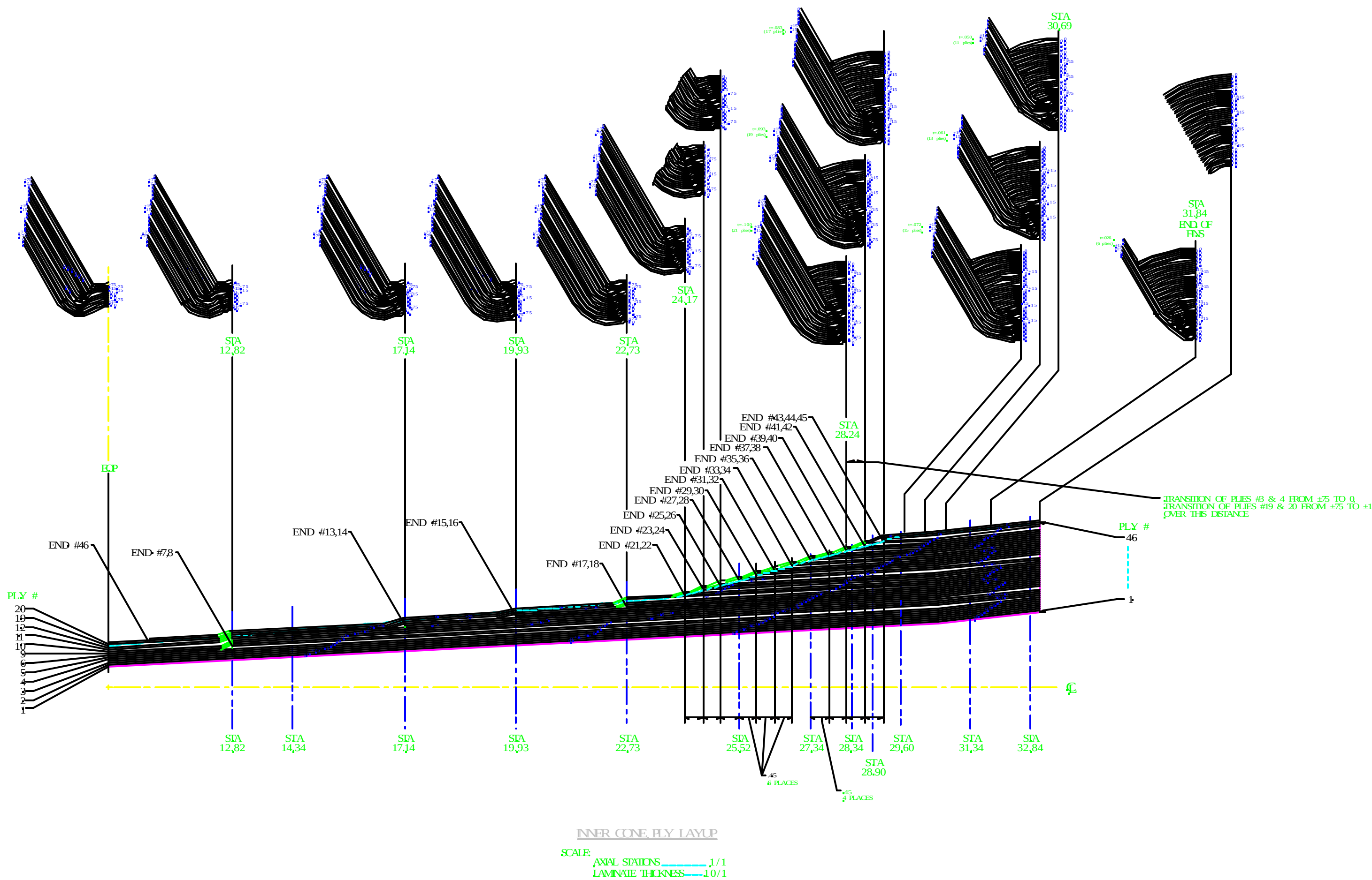
FABRICATION STEPS

- **Receive Material**
  - Unidirectional Prepreg Tape
- **Make Fabrication Kits**
  - Cut Gore Patterns with Drop-Offs
- **Lay Up Gore Sections on Male Tool**
  - Controlled Section Thickness Using Ply Drop-Off
  - Partial De-Bulk on Male Tool
- **Close Tool into Female Tool**
  - 250°F Cure Processing
  - Deflash
  - Trim Part to Length
- **Bond Aluminum Face Plates on Sabot Fwd End**

D2 Channel Ply Lay-Up

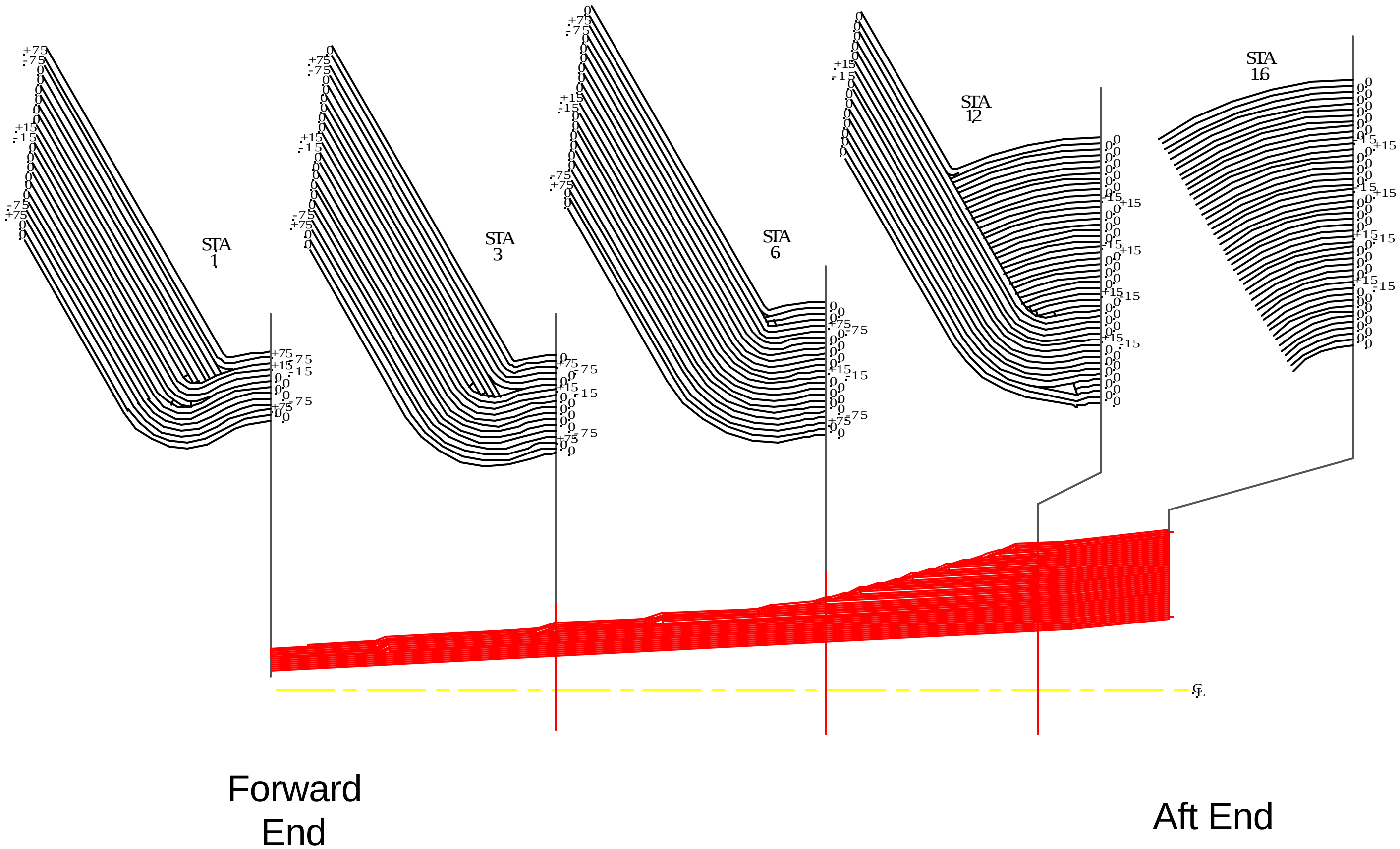


Channel Lay Up

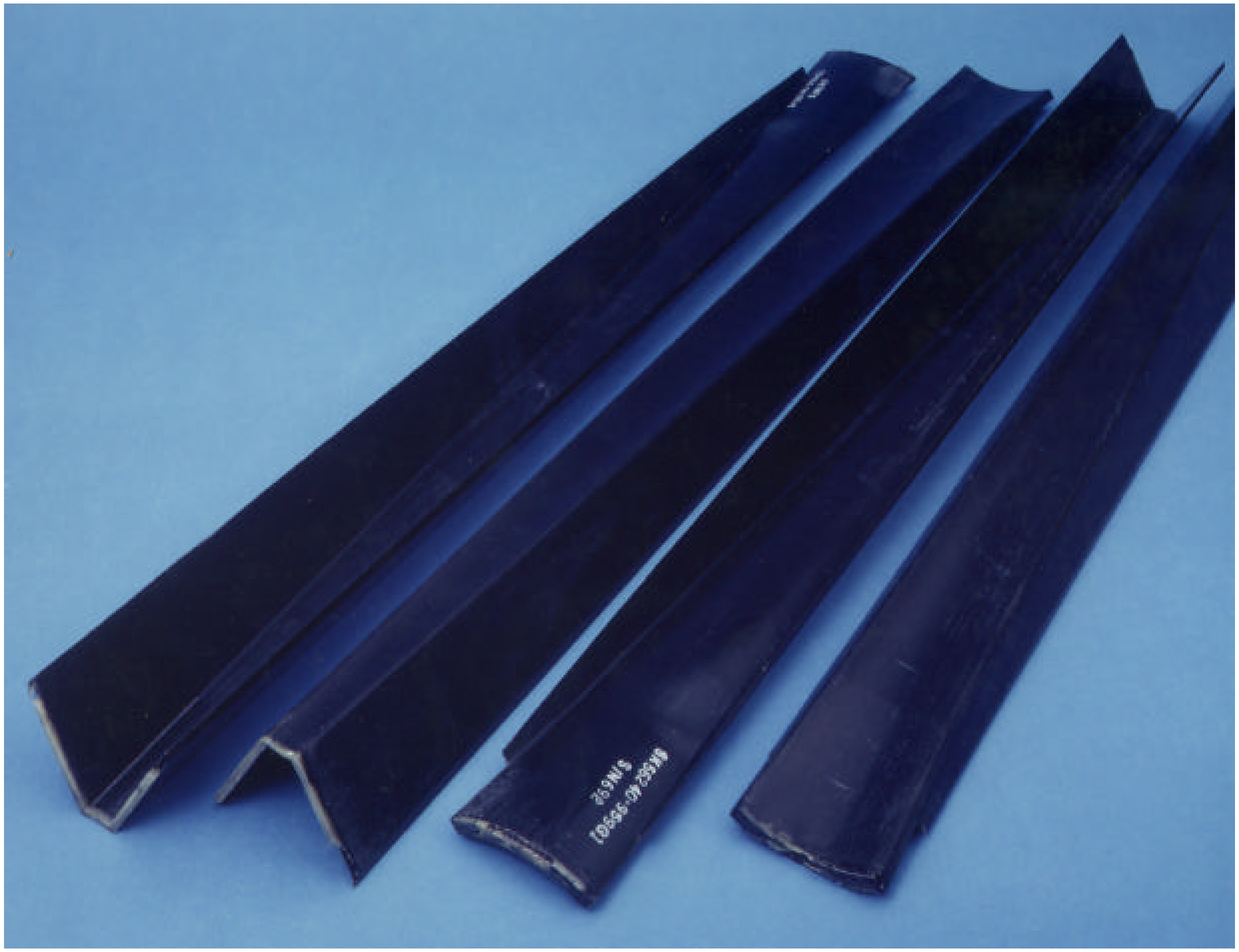


we offer composite solutions...

Channel Sabot Ply Architecture Schematic Showing Ply Drop-Offs



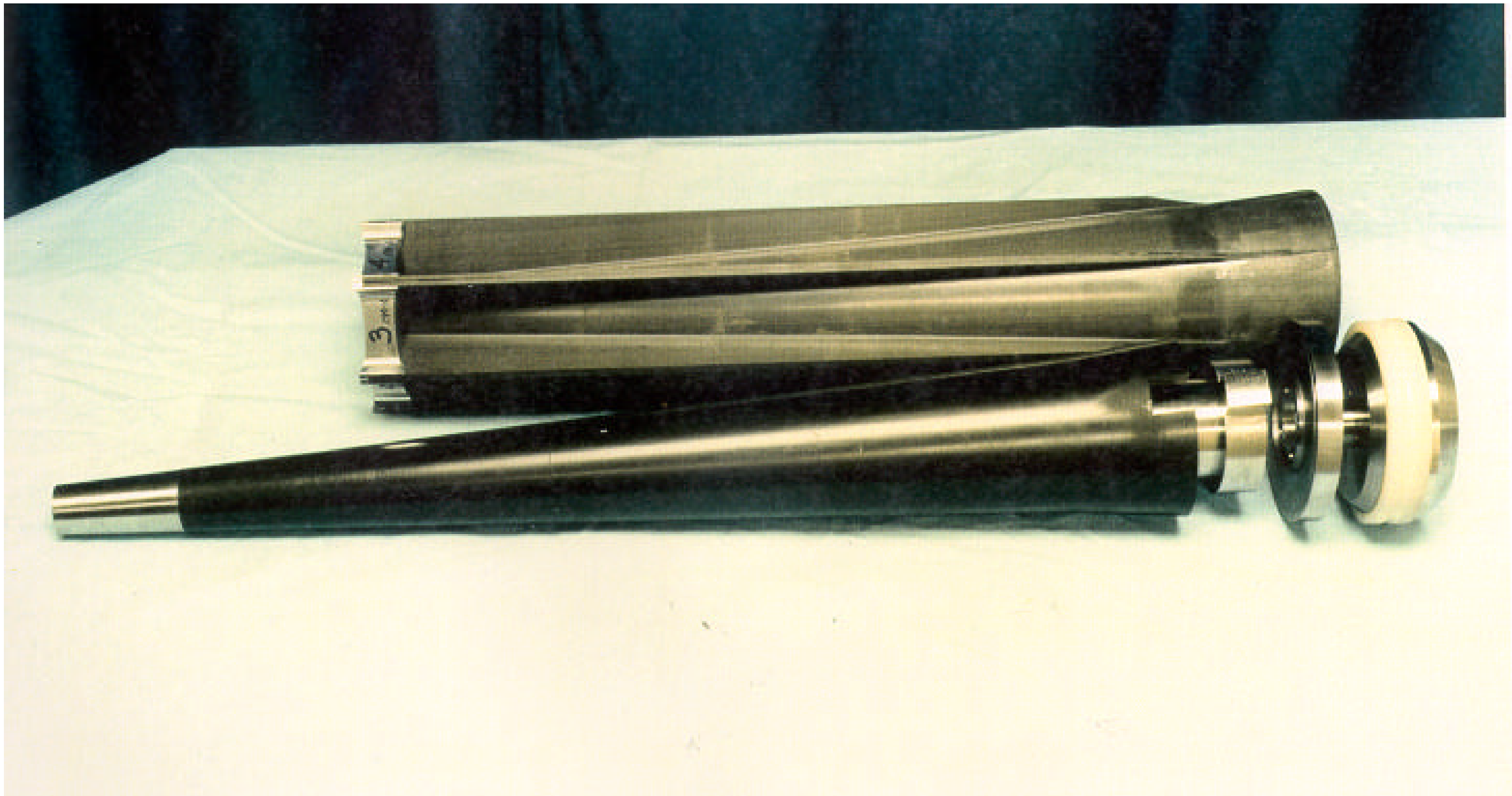
As Fabricated Composite Channel Sabot



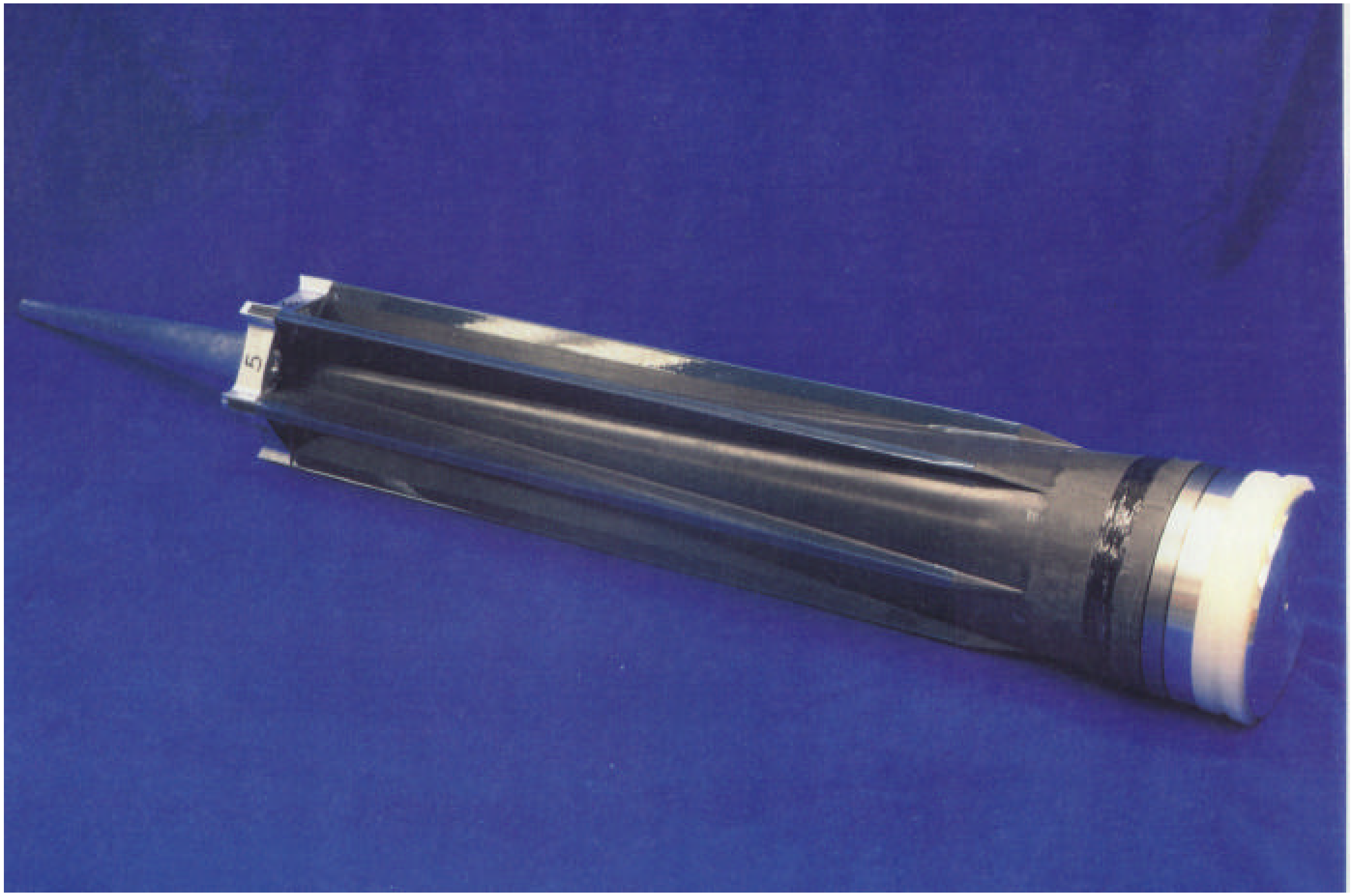
SPARTA
Pride In Performance

we offer composite solutions...

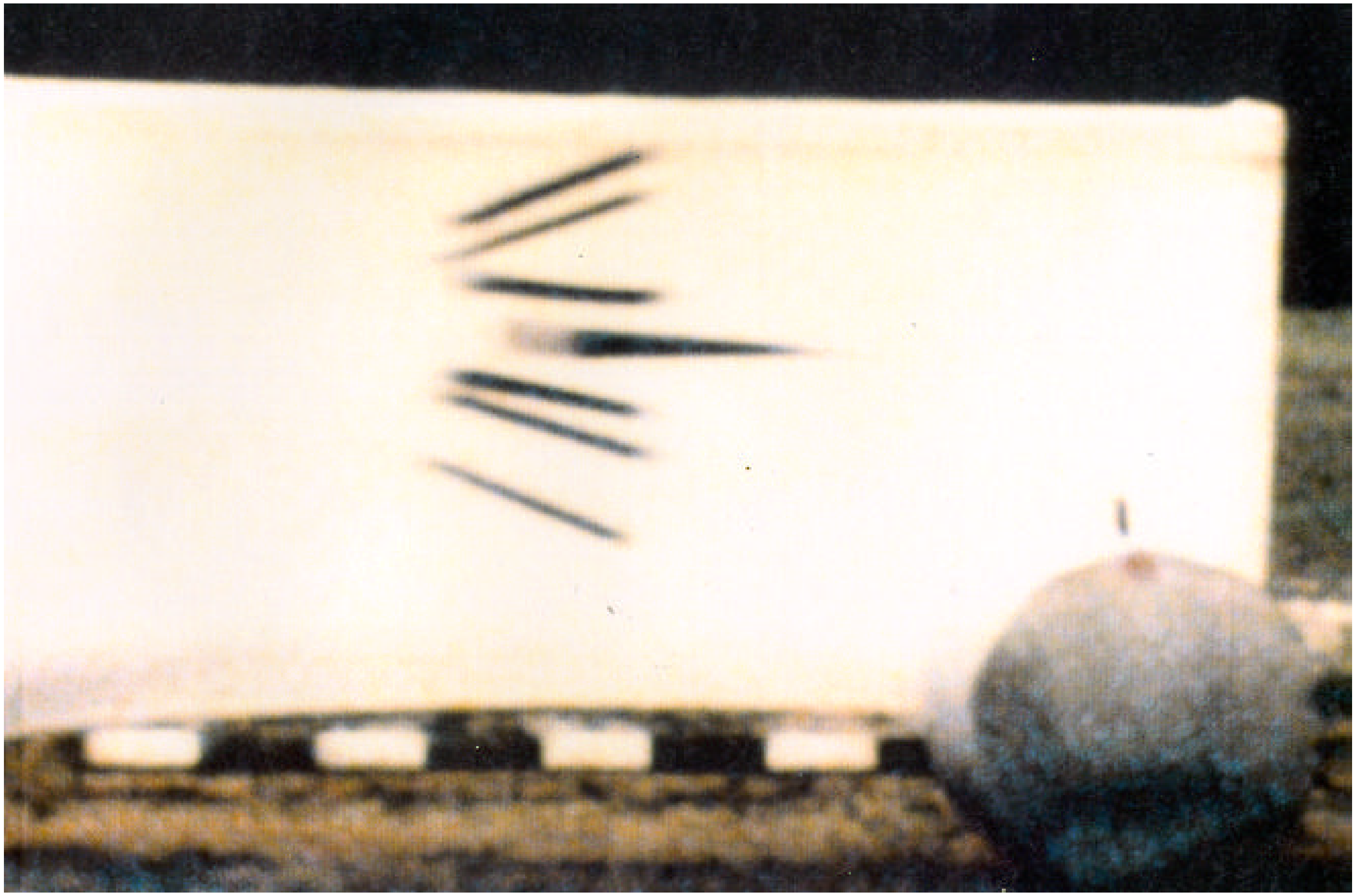
105mm ETC Hardware with Channel Sabot



105 ETC Channel Sabot Round Assembly



105mm Channel Sabot ETC Test Flight Showing Clean Sabot Separation



SPARTA
Pride In Performance

we offer composite solutions...

D2 Flight Test Showing Clean Sabot Separation (Channel Sabot)

SPARTA
Pride In Performance

we offer composite solutions…

Channel Sabot Summary

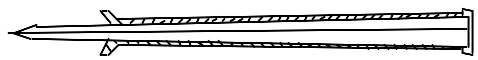
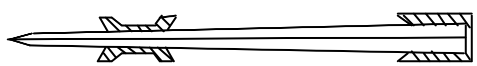
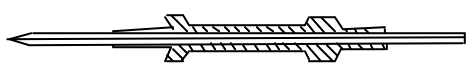
- **Channel Sabot Mass - 2.75 lbs**
  - » **48% of the Launch Mass**
- **6 Total Shots**
  - **Exit Velocities Range from 1.73 km/sec to 1.81 km/sec**
  - **Peak Acceleration 48.6 kgees to 52.8 kgees**
- **No Failures**
  - **Last 4 Shots Had On-Board Electronics (RF Data to Ground Station to Demonstrate 2-Way Communication w/Ground)**

Summary

- **Conical Sabot**
  - **Lightweight Design**
  - **Complex Fabrication**
  - **Inconsistent Performance**
    - Excursions of In-Bore Pressure Caused Collapse of Cone
  - **No Fabrication Anomalies**
- **Channel Sabot**
  - **Slightly Heavier Than Conical Design**
  - **No In-Bore or Flight Failures**
  - **Launch Acceleration in Excess of 52 Kgees**
- **Standard Material (Carbon/Epoxy) Can Be Successfully Used to Fabricate Lightweight, High Performance Sabots for Ballistic Applications**
  - **Requires Experience and Attention to Detail**

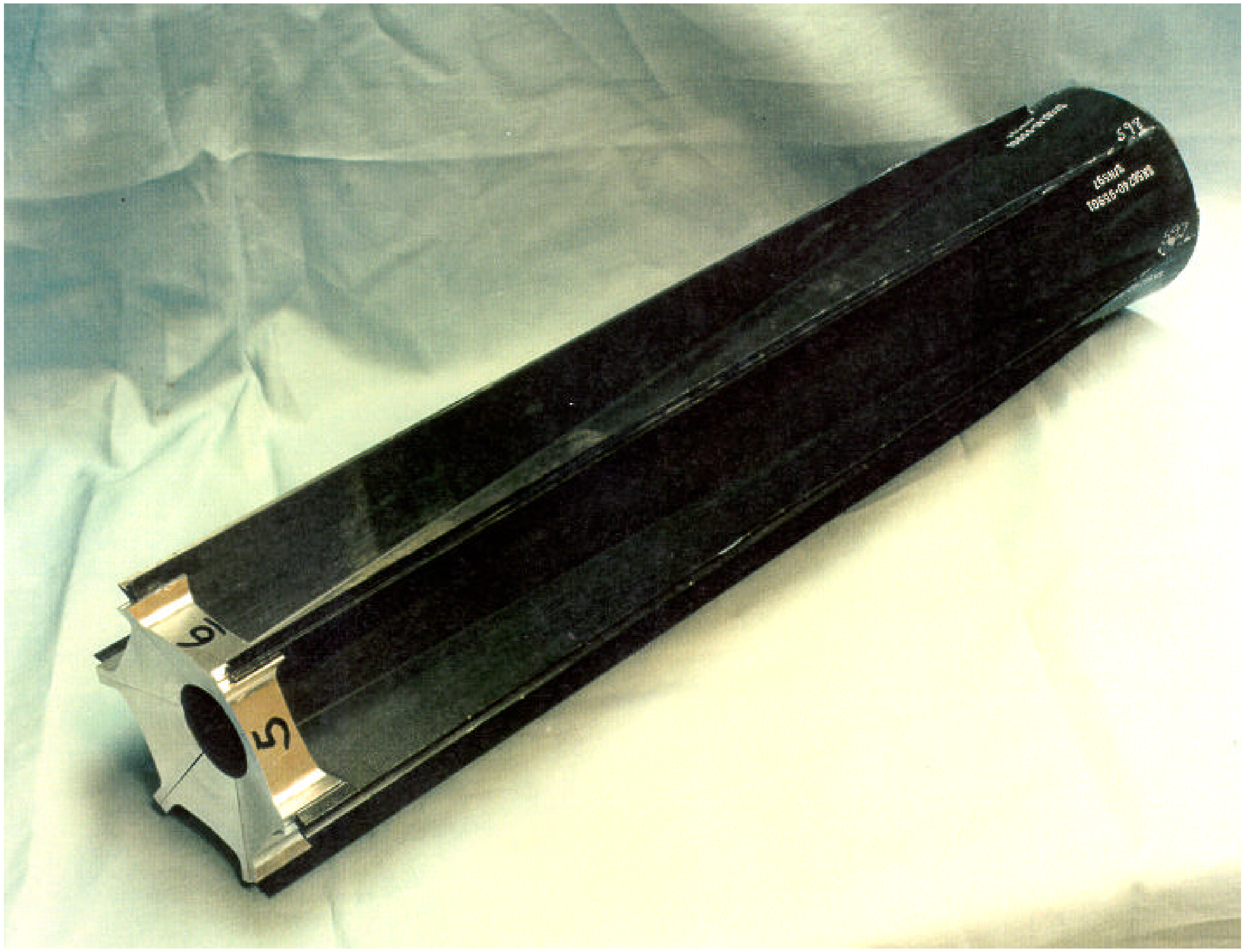
BACKUP CHARTS

Composite Sabots Designed by SPARTA

SABOT	ATTRIBUTES	ISSUES
 **Standard, Conformal, Base Pushing** Typically used for Conical, Aerodynamically Stable Projectiles	Straight Forward to Design & Fabricate, Does not excessively Load Projectile, Loads Projectile in Compression	Heavy Design, Requires High Compressive Strength Materials
 **Segmented, Base Pushing** Used for Conical Projectiles	Lightweight Split Design, Minimum Material, Loads Projectile in Compression	Forward Segment Loads Projectile, Projectile not Supported Laterally Along Length
 **Midriding** Used for Anti-Armor/ Penetrator Rounds	Subjects Projectile to both Tensile And Compressive Loads, Loads Transferred to Projectile by Shear	Potential for Increased Balloting & Pitching Loads, Requires High Shear Strength Design, Complex loading

SPARTA Pride In Performance

Graphite Epoxy Channel Sabot



SPARTA
Pride In Performance

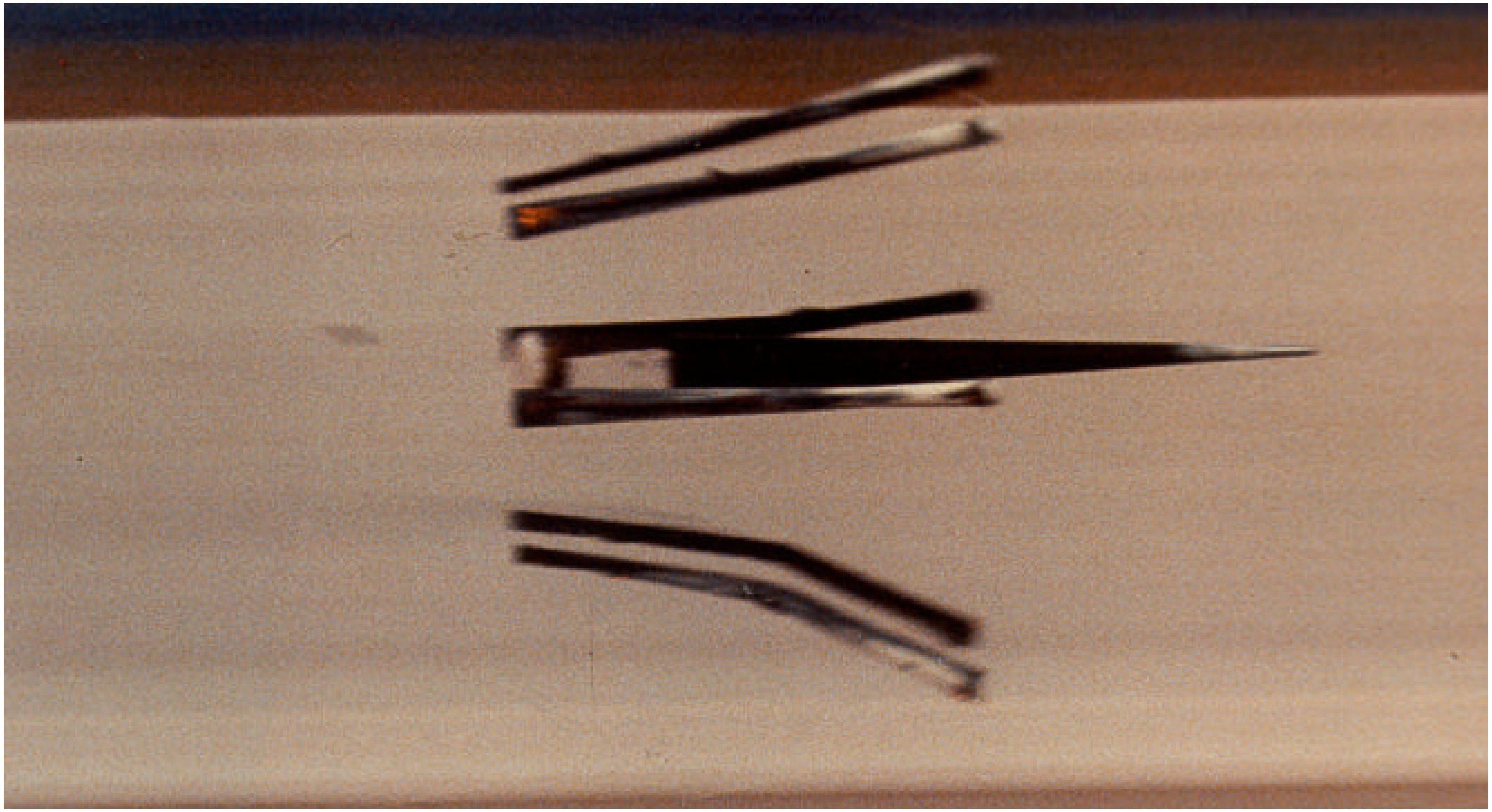
we offer composite solutions...

105mm ETC Test Hardware

ETC Launcher used at Eglin

we offer composite solutions...

Conical Sabot Separation

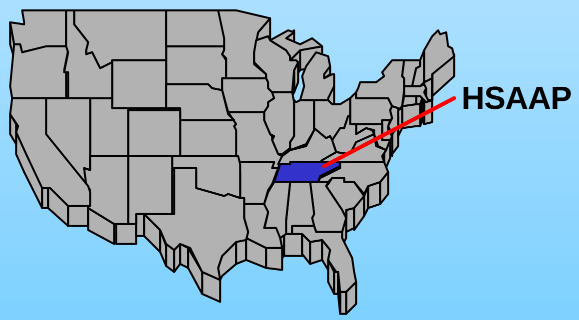


we offer composite solutions...

NDIA 2000 TECHNOLOGY AVANCEMENTS IN MUNITIONS MANUFACTURING SYMPOSIUM

UPDATE ON THE MODERNIZATION OF THE HOLSTON ARMY AMMUNITION PLANT (HSAAP)

BY ANDREW WILSON
NIGEL HOUSE
JOHN PETHERBRIDGE



ROYAL ORDNANCE NORTH AMERICA, INC
4509 West Stone Drive
Kingsport, TN 37664

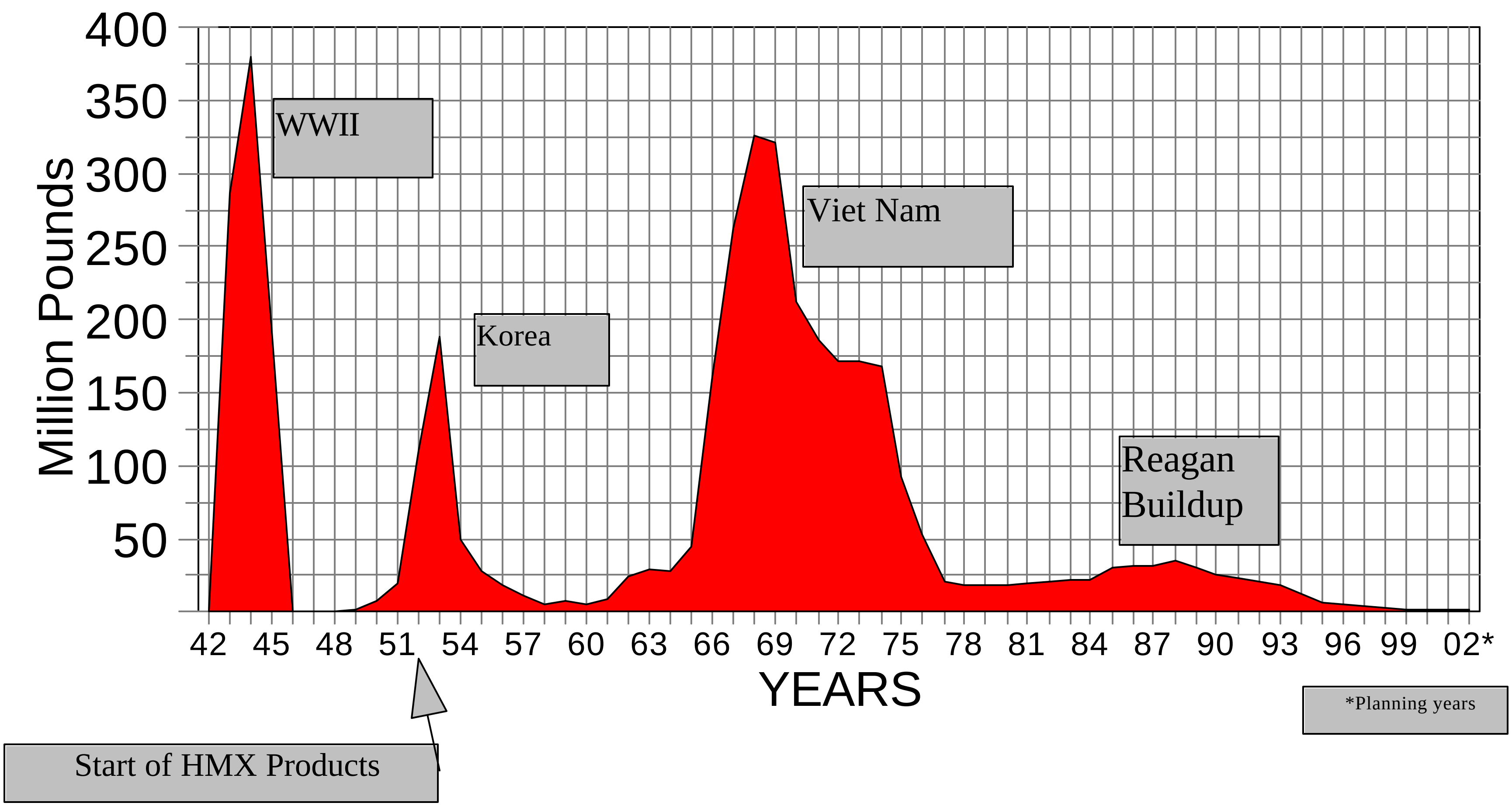
BAE SYSTEMS

HSAAP MODERNIZATION
Background

- U.S Producer of RDX/HMX Products Since 1943
- Historically Configured for Very High Volumes
  - »1m LB / day

BAE SYSTEMS

HSAAP - HISTORICAL PRODUCTION LEVELS



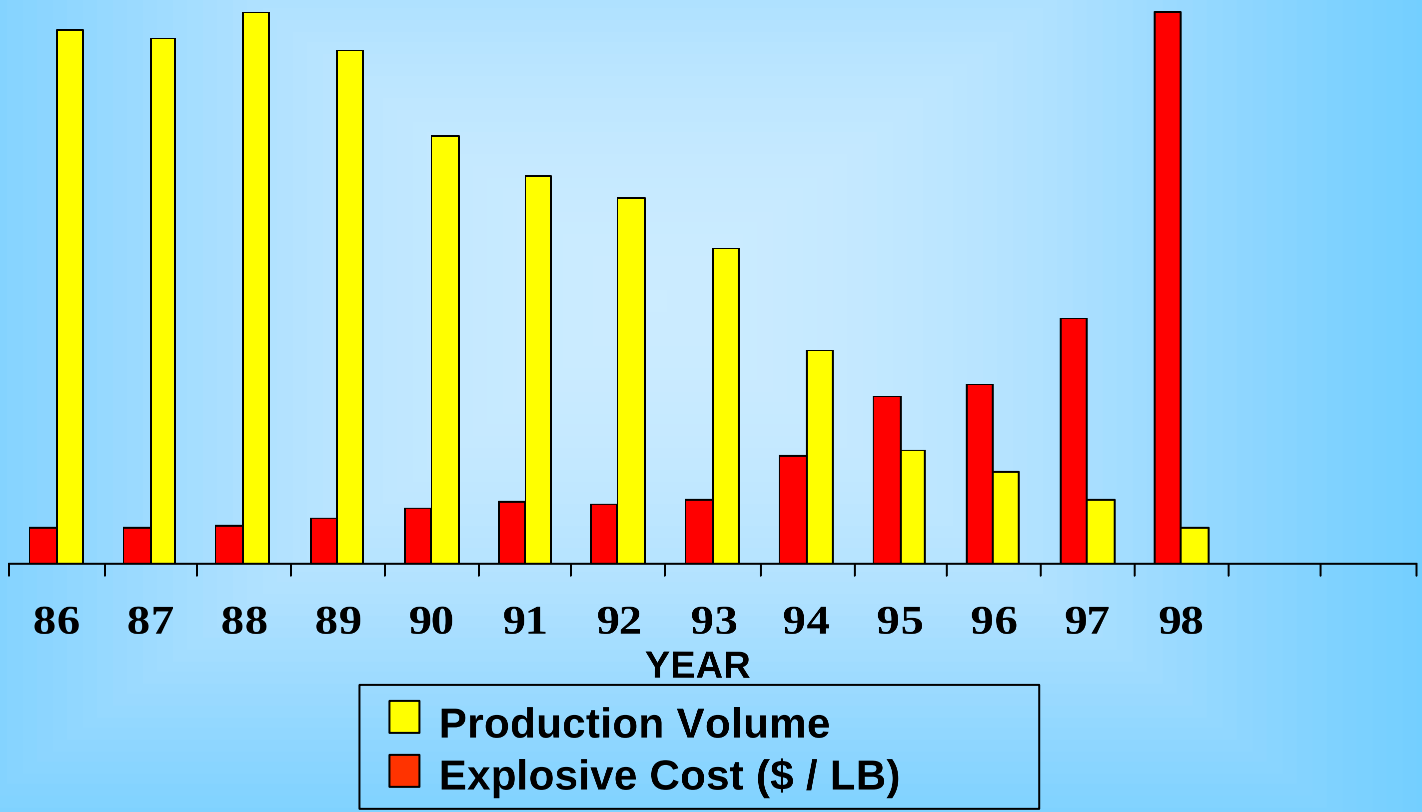
BAE SYSTEMS

HSAAP MODERNIZATION
Background

- U.S Producer of RDX/HMX Products Since 1943
- Historically Configured for Very High Volumes
  - »1m LB / day
- Operating on Modern Peacetime Volumes
  - »2m LB / year
- Escalating Product Costs

BAE SYSTEMS

HSAAP - HISTORICAL PRODUCT COSTS



BAE SYSTEMS

HSAAP MODERNIZATION
Background

- U.S Producer of RDX/HMX Products Since 1943
- Historically Configured for Very High Volumes
  - »1m LB / day
- Operating on Modern Peacetime Volumes
  - »2m LB / year
- Escalating Product Costs
- **Resulted in Competition to Supply Explosives**
  - **XMAT Contract Awarded to RONA**

BAE SYSTEMS

HSAAP MODERNIZATION
Summary

- **$15m Investment (1999 / 2000)**
  - **Infrastructure Upgrades**
  - **Minimizing Manual-Handling of Product**
  - **Reducing the Number of Operating Buildings**
    - **Centralized control room**
- **Maintaining Product Quality**
  - **Same Equipment, People & Processes**
    - **»90% RONA staff are former HDC employees**

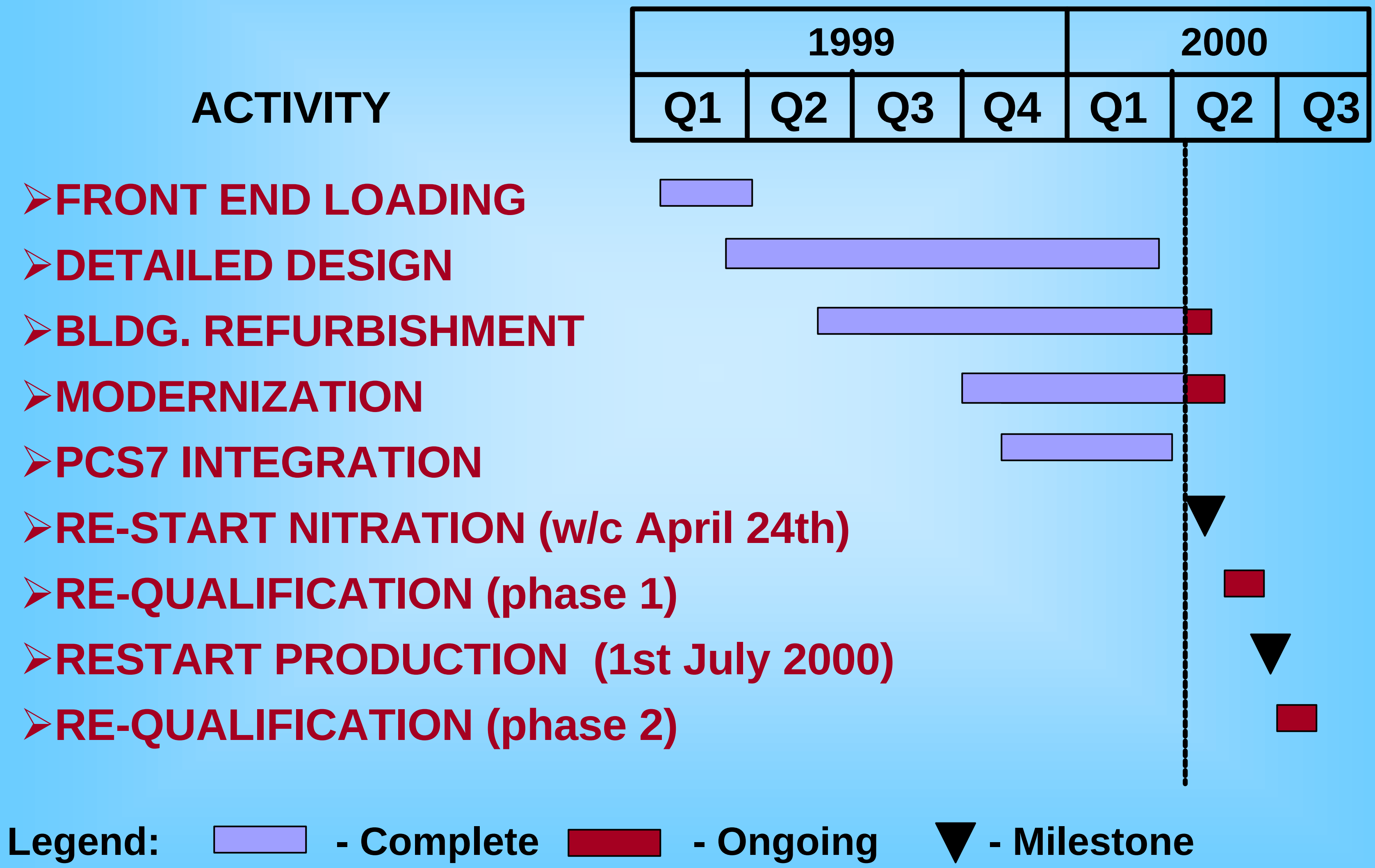
BAE SYSTEMS

HSAAP MODERNIZATION
Progress

- Design Work Completed
- New Gas Fired Boiler for Acid Plant
- Hydraulic Motors Installed
- Product Lifting Tables Installed
- Centralized Control Room Established

BAE SYSTEMS

HSAAP MODERNIZATION
Project Time Scale & Status



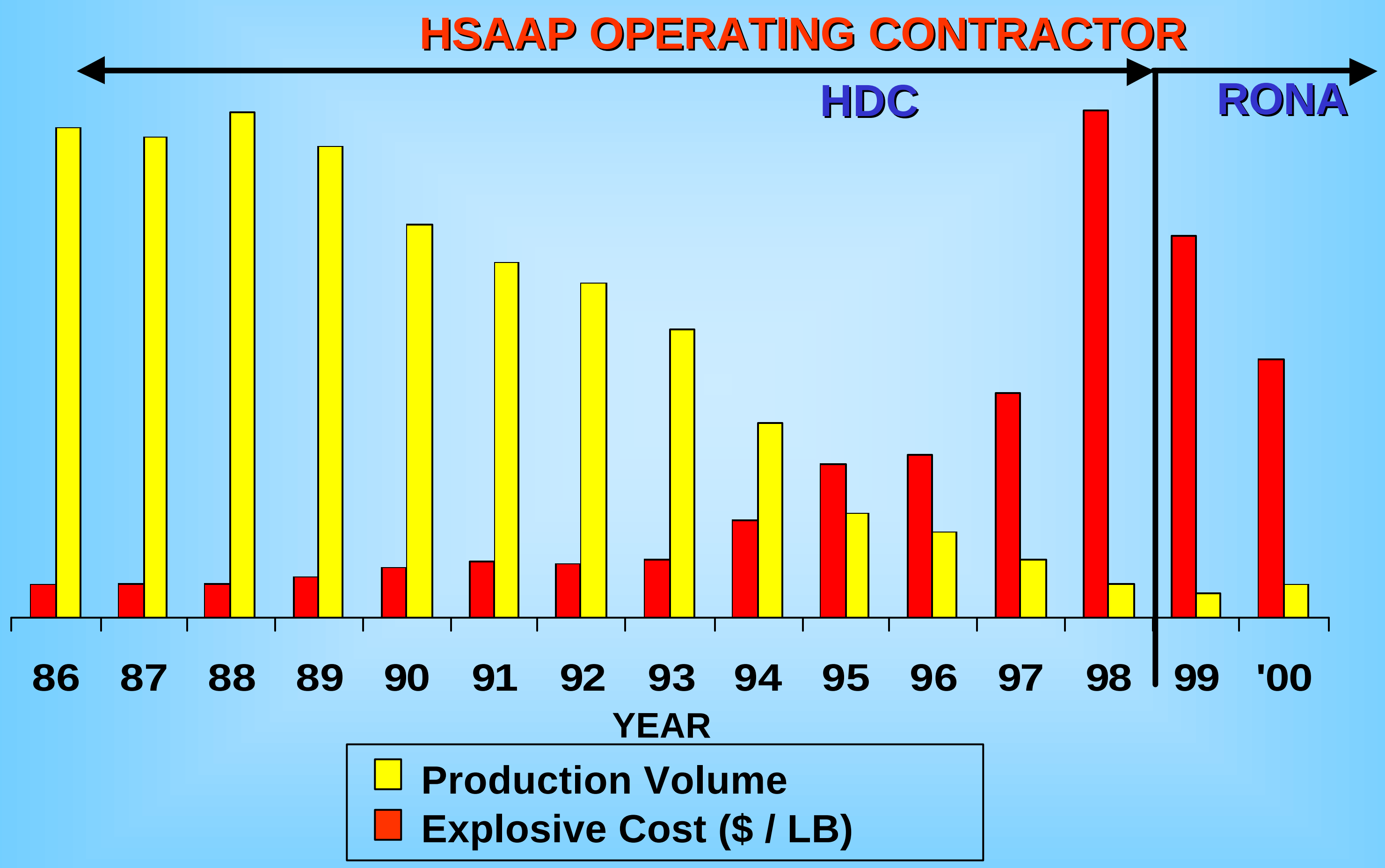
BAE SYSTEMS

HSAAP MODERNIZATION
Impact on Manufacturing Process

- **NO CHANGE TO HSAAP MANUFACTURING PROCESSES**
  - **Same Equipment**
  - **Same Processes, Procedures and Specifications**
  - **Same People**
    - **»90% of RONA Employees (115) are ex-HDC (1998)**
    - **Additional recruitment of ex-HDC staff planned (2000)**
- **PRODUCT RANGE UNCHANGED**
  - **Additional Products Planned**

BAE SYSTEMS

HSAAP MODERNIZATION
Impact on Product Costs



BAE SYSTEMS

HSAAP MODERNIZATION
Impact on Product Costs - Examples

PRODUCT	HDC *1997/8 ($/lb)*	RONA *1999/2000 ($/lb)*
PBXN-5	55.26	< 22
PBXN-9	31.65	< 19
CXM-3	9.11	< 7.5
HMX / Cl. 1	37.77	< 22
RDX / Cl. 1	15.91	< 6
RDX / Cl. 5	15.91	< 7

NOTE - HDC's production volume in 1997 was approximately twice the projected RONA volume in 2000. Prices not adjusted for inflation.

BAE SYSTEMS

HSAAP MODERNIZATION
HSAAP Re-qualification

- **HSAAP PRODUCTS NEED SOME LEVEL OF RE-QUALIFICATION**
  - **To Confirm Processes and products are Unchanged**
- **RE-QUALIFICATION PLANNING COMMENCED (Q4/99)**
  - **Controlled by U.S. Army, Navy, Air Force, Marine Corps**
- **RONA RE-QUALIFICATION PROCESS**
  - **Manufacture Full Scale Batches of Products**
  - **On-site and off-site Testing**
  - **Manufacture and Testing Witnessed by DoD Representative**
  - **Re-qualification is in Two Phases To Meet Customer Needs**
- **TIME SCALE**
  - **Re-qualification to Start in May 2000**

BAE SYSTEMS

HSAAP MODERNIZATION
Conclusions

- HSAAP Modernization is the Cornerstone of RONA's Plans to Reduce the Cost of Explosive Manufacture
- Key modernization Objectives Include Improved Infrastructure, Minimized Product Manual-Handling and Reduced number of Operating Buildings (38 to 22)
- Product Range and Manufacturing Skills Unaffected; Critical Skills Have Been Retained by RONA
- HSAAP Re-qualification Planning Process Agreed
- HSAAP Resumes Production from w/c 24th April 2000

BAE SYSTEMS

HSAAP MODERNIZATION
Acknowledgements

Jerry Hammonds (RONA, Manager Explosives)

Bill May (RONA Modernization Project Manager)

Dan Gothard (RONA Project Engineer)

BAE SYSTEMS